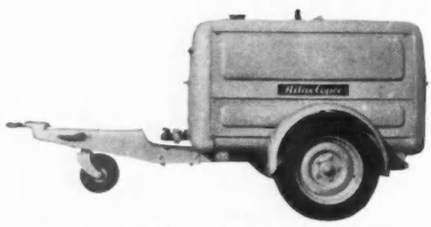
THE ENGINEER

FEBRUARY 26, 1960 | 28 ESSEX STREET, STRAND, LONDON, W.C.2 | TWO SHILLINGS

VT Compressors

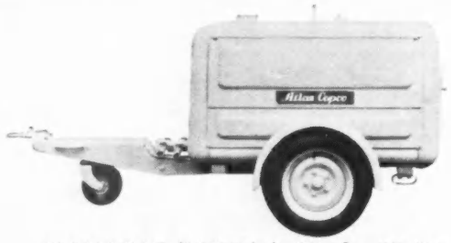
Smaller, Lighter, more Powerful

VT3

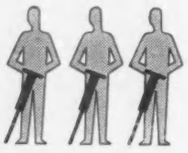


Weight 2,180 lb (990 kg) ★ 115 c.f.m. 3.2m³/m

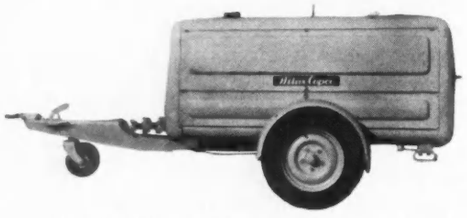
VT4



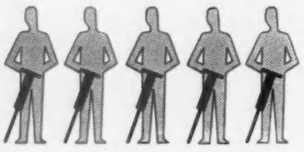
Weight 2,310 lb (1,050 kg) ★ 160 c.f.m. 4.5m³/m



VT5

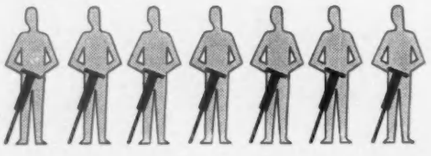


Weight 2,900 lb (1,315 kg) ★ 225 c.f.m. 6.4m³/m



VT6

Weight 3,590 lb (1,630 kg) ★ 315 c.f.m. 8.9m³/m



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Established 1856

No. 5431 **FEBRUARY 26, 1960** VOL. 209

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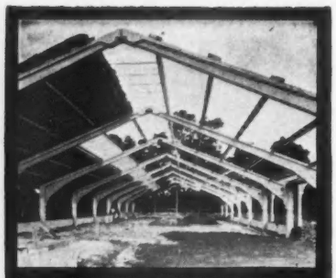

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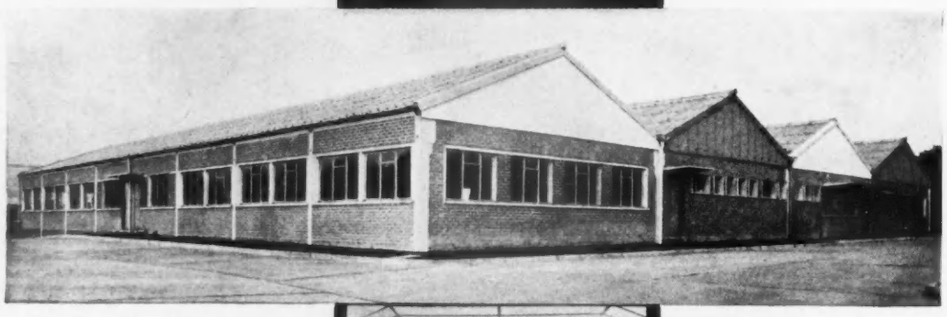

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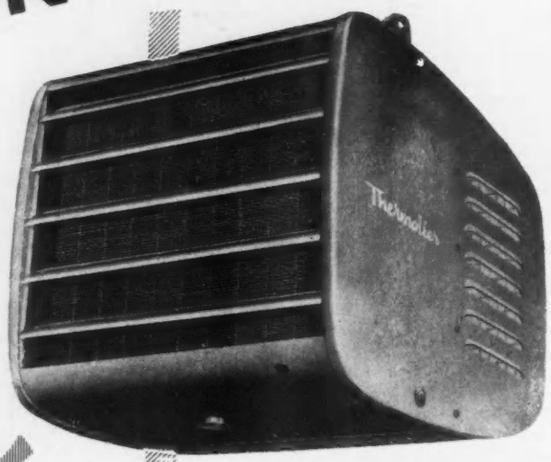

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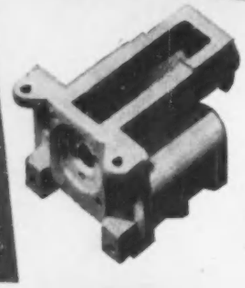

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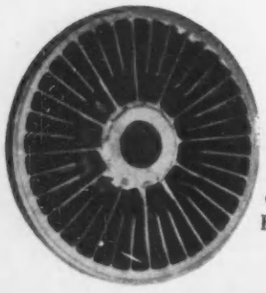

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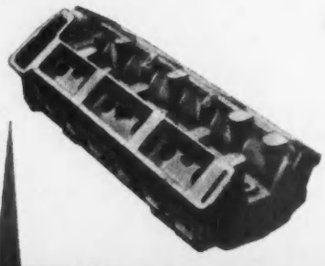

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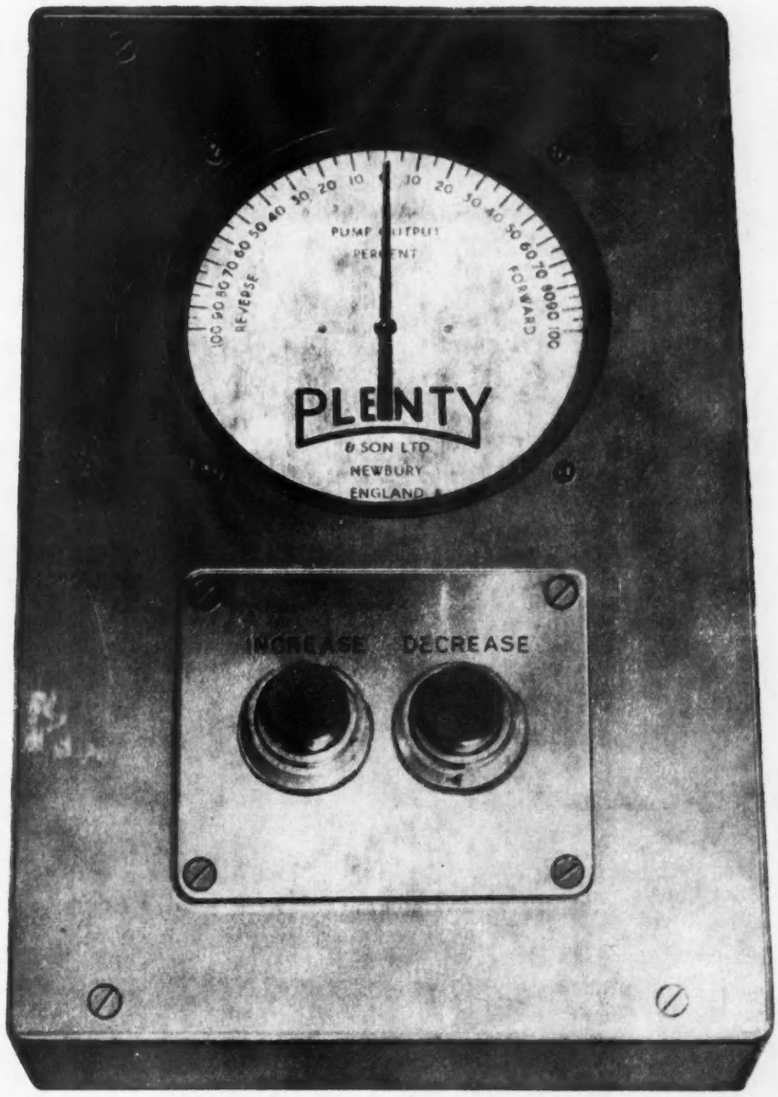

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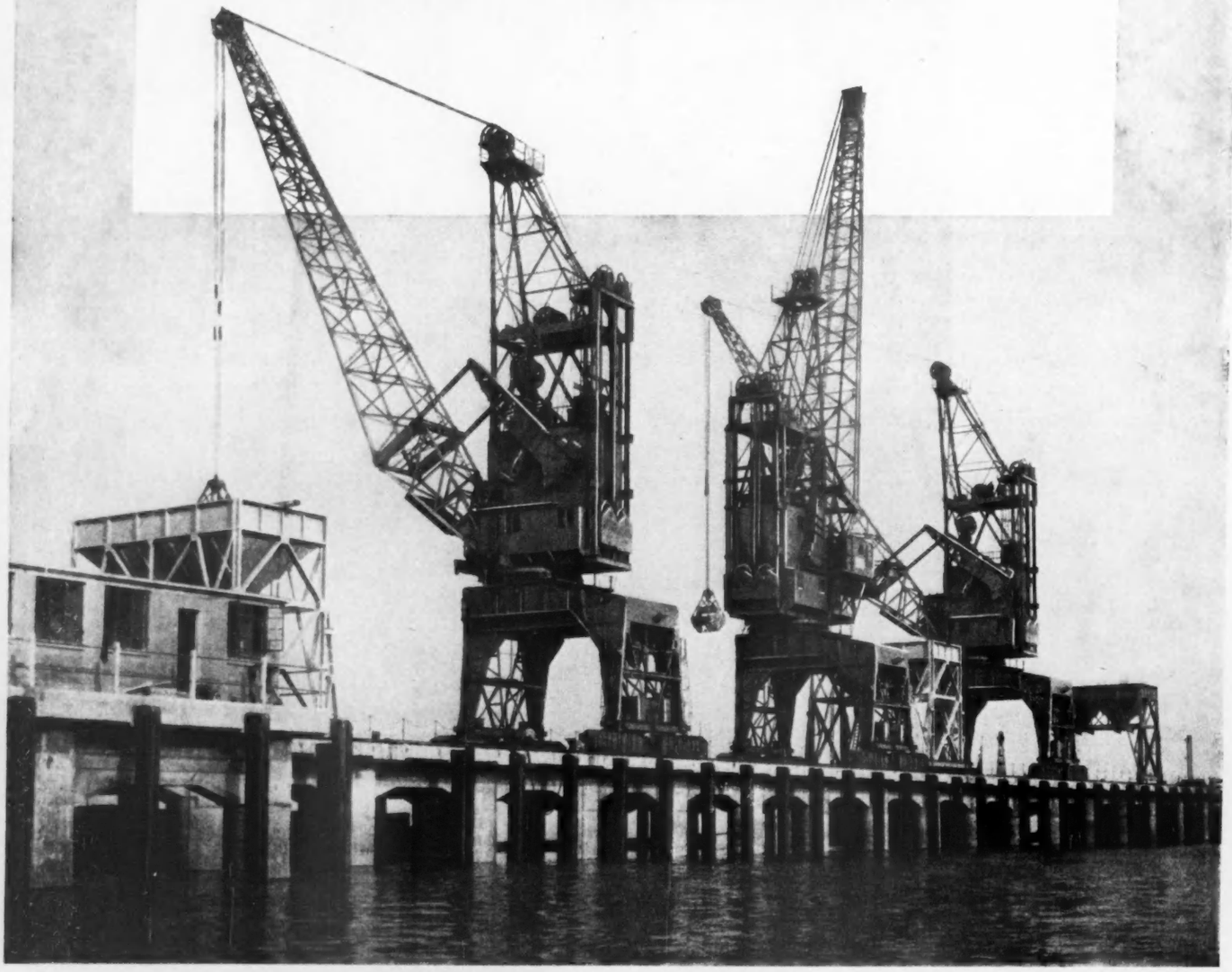

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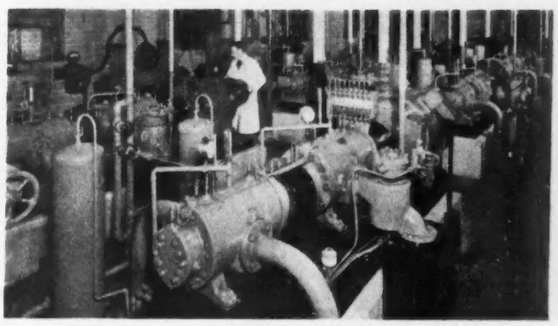

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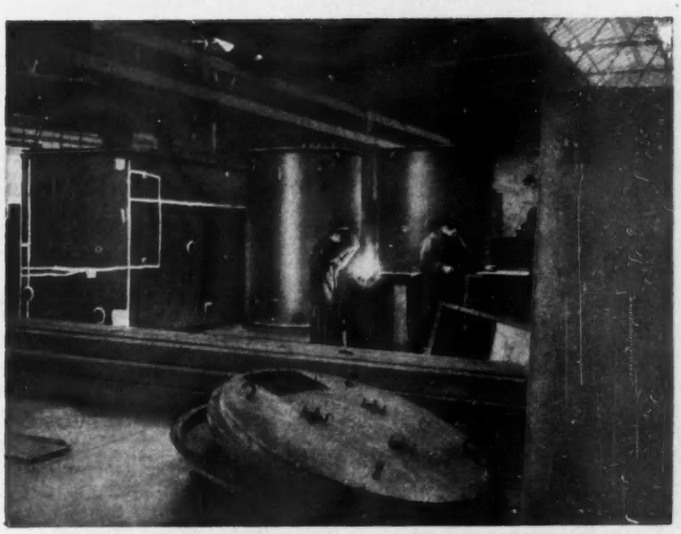

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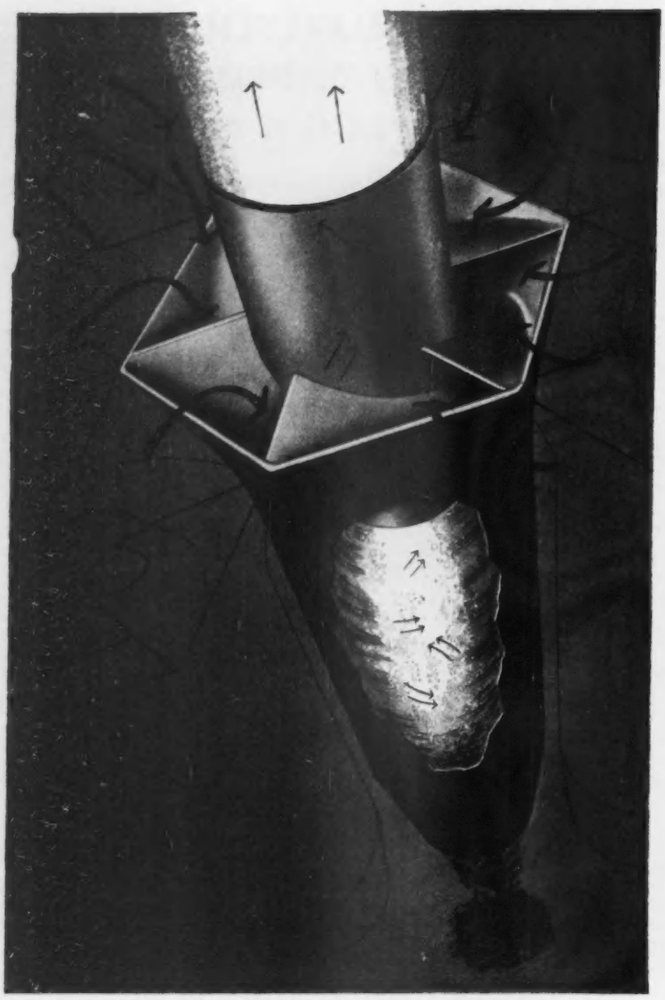

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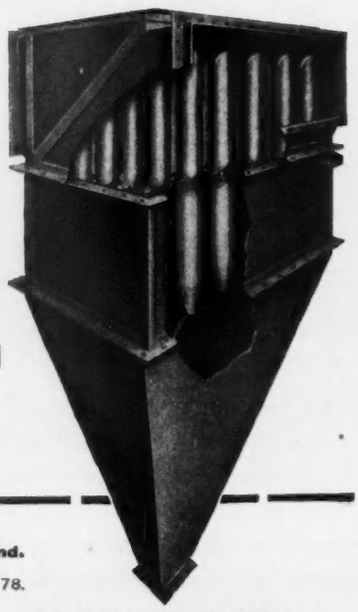

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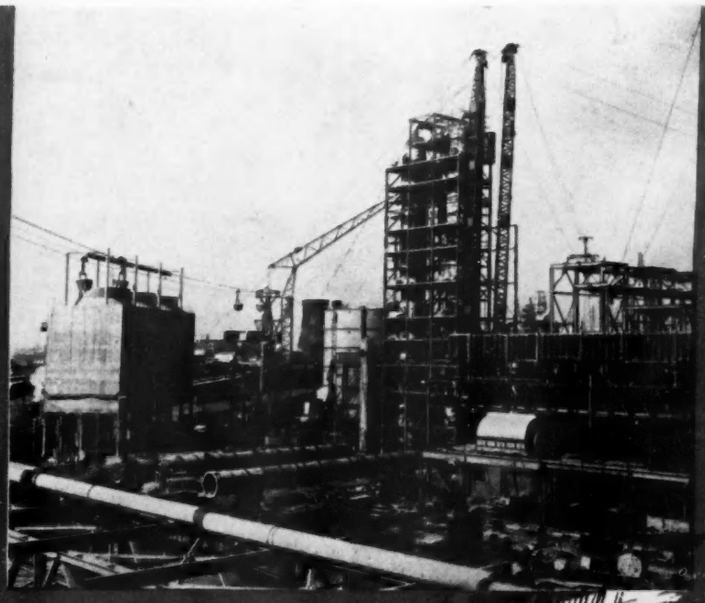

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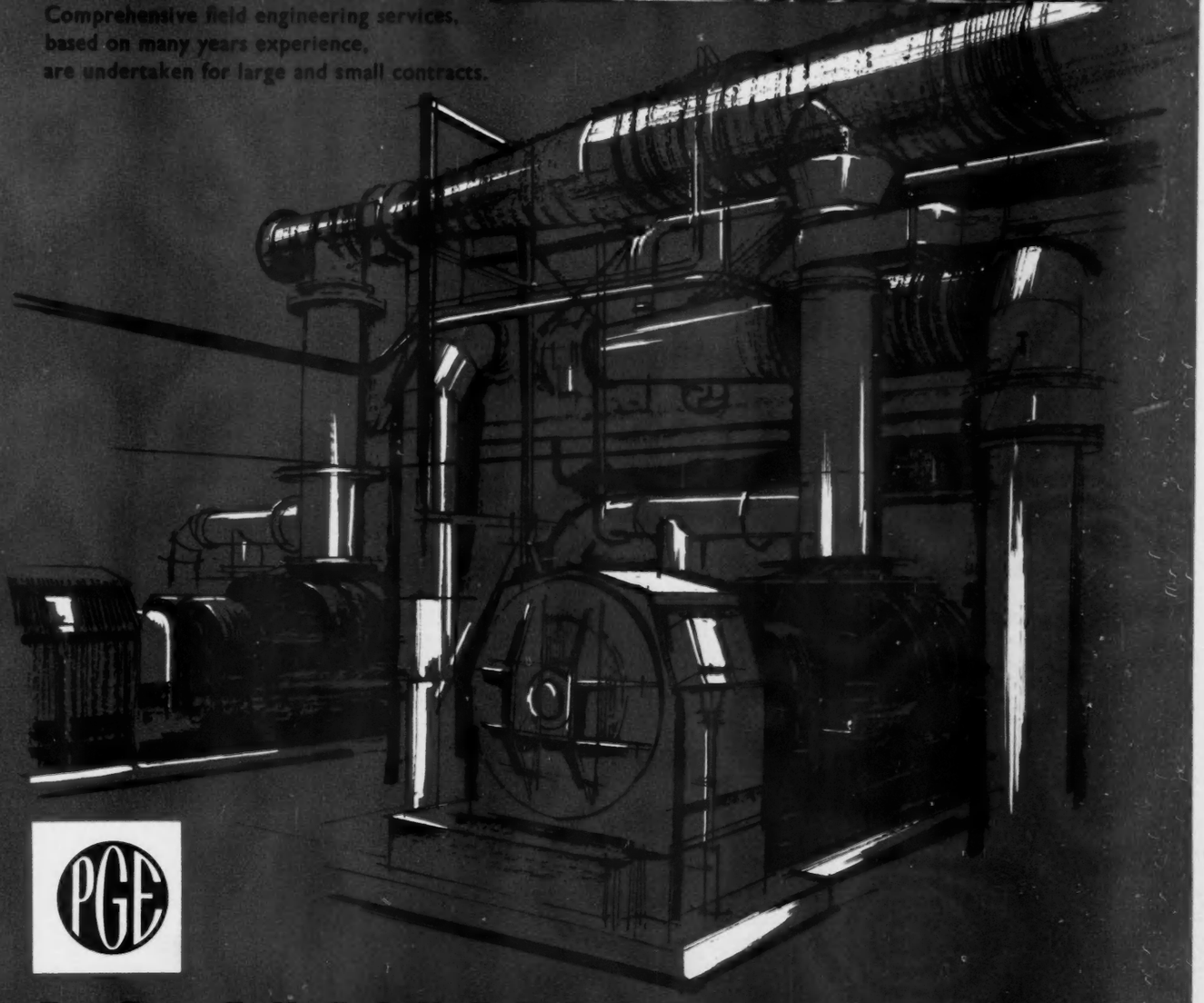

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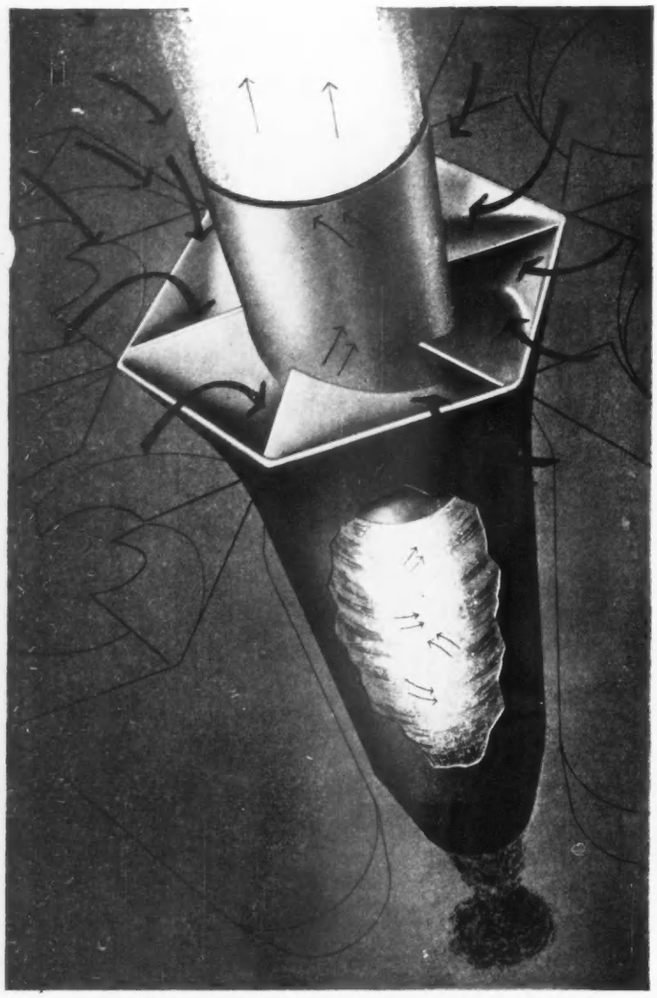

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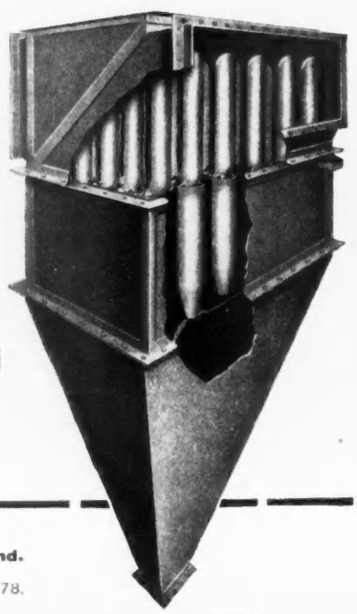

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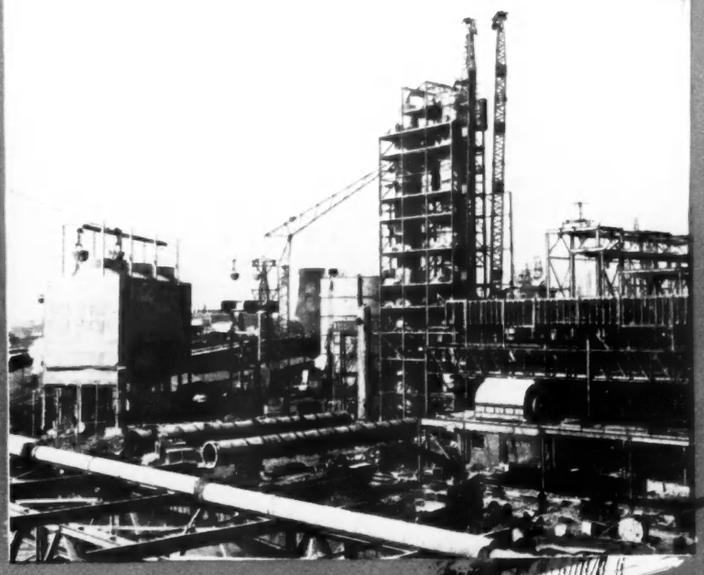

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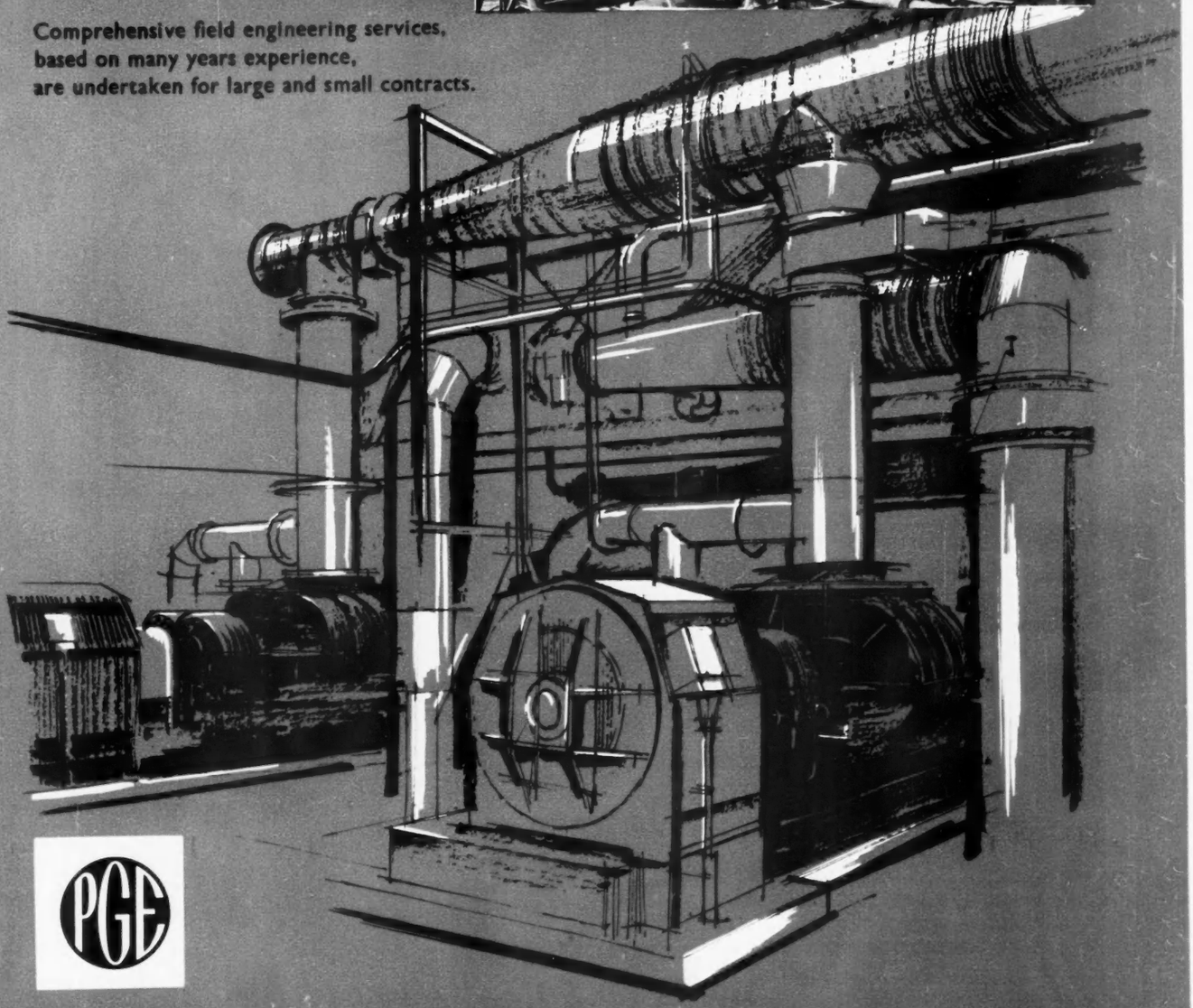

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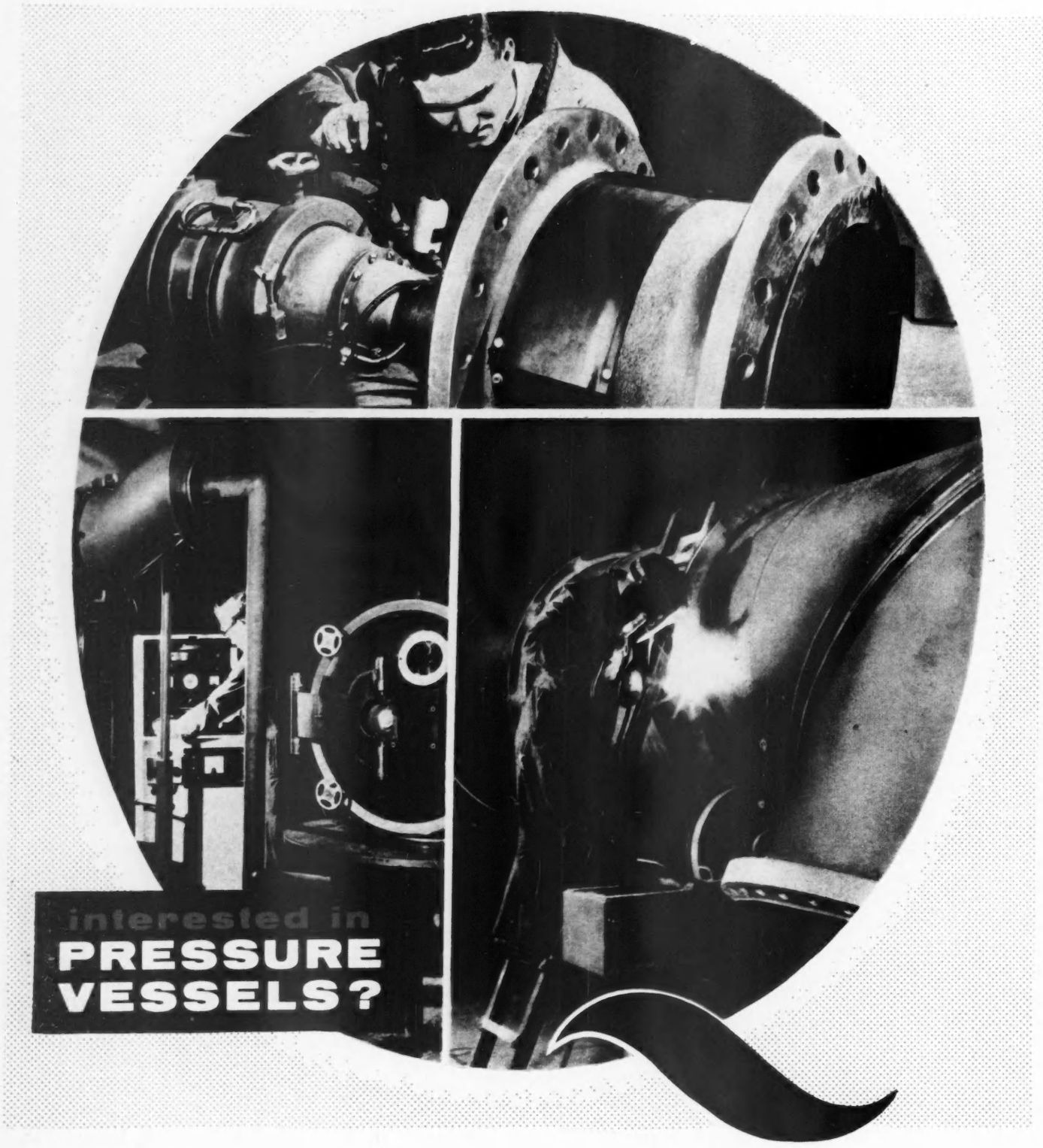

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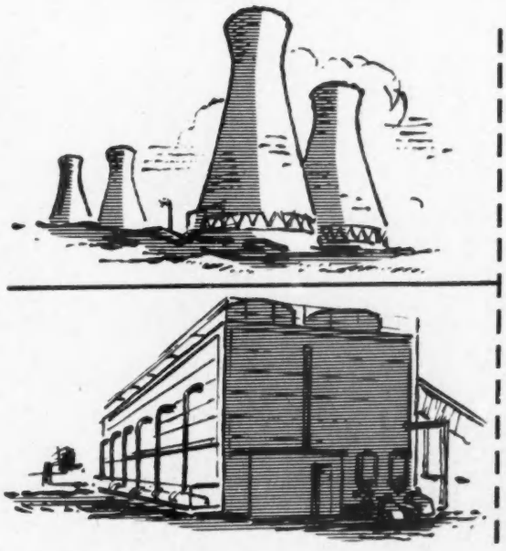

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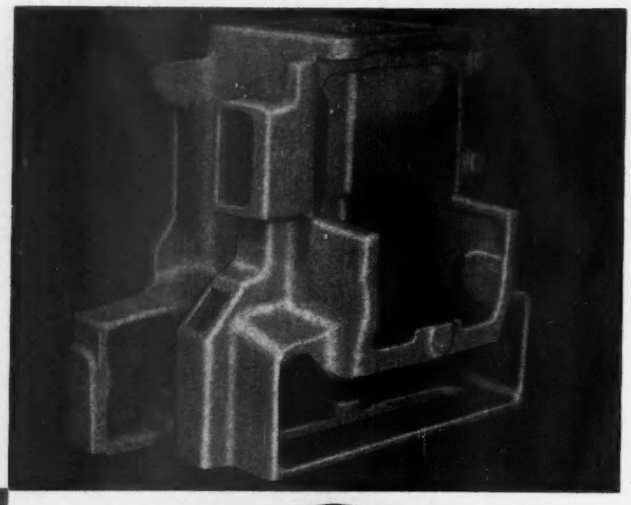

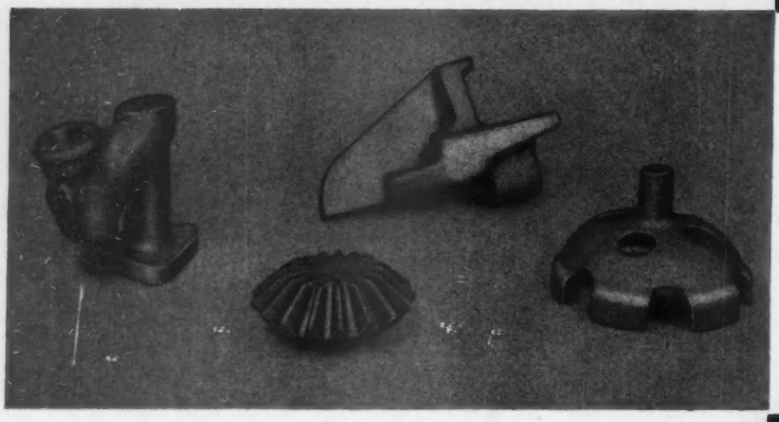

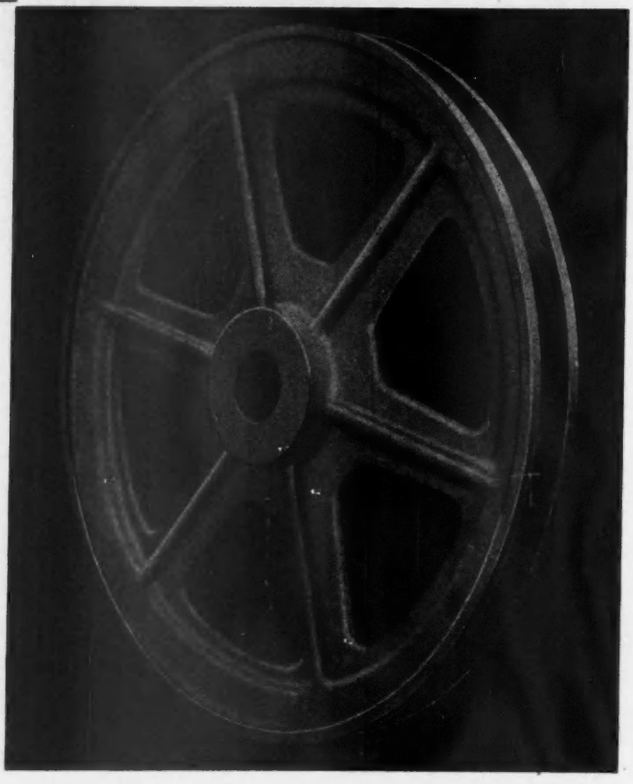

We can supply Castings up to 3 Tons in weight.

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Our Technical Representative will be pleased to call and discuss your particular requirements.

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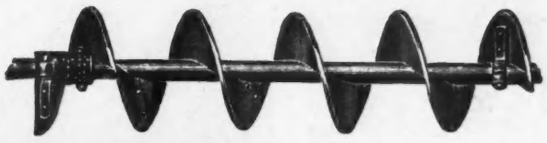

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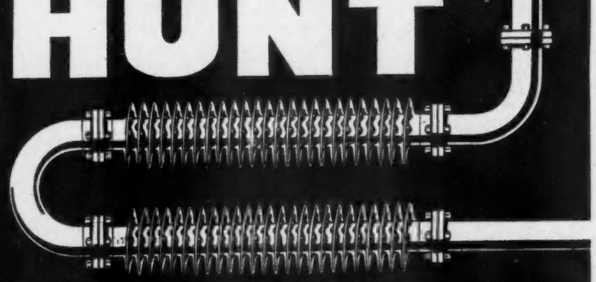

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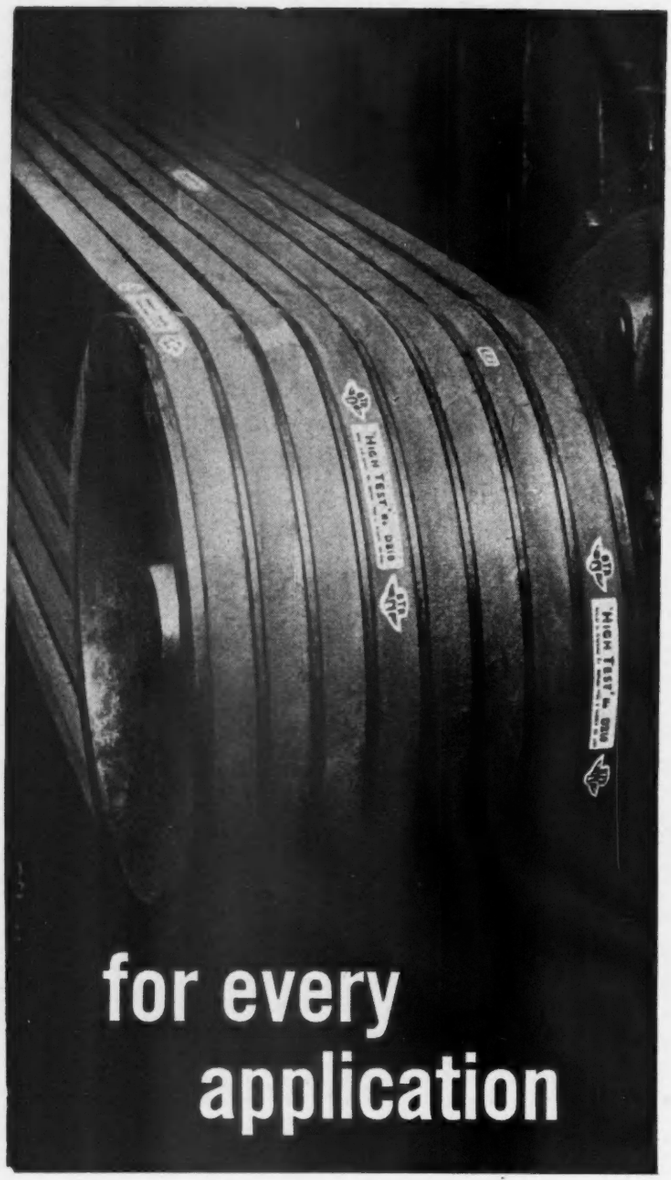
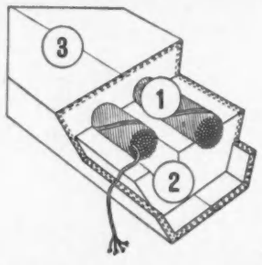


there's a BTR High Test V-Belt



This diagram shows (1) the load-carrying members (2), the rubber cushion and (3) the 2 ply cover of specially woven wear resisting material of a BTR High Test V-Belt. This Grommet construction is available in Sections B, C, D and E.

A Grommet-constructed BTR High Test V-Belt pulls a heavier load with a higher safety factor and greater gripping power. It gives you more horsepower, more output for electricity consumed and a far longer belt life. The spirally wound construction of the Grommet ensures that each individual cord winding carries an equal share of the load. And there's a BTR High Test V-Belt specially designed for every application.

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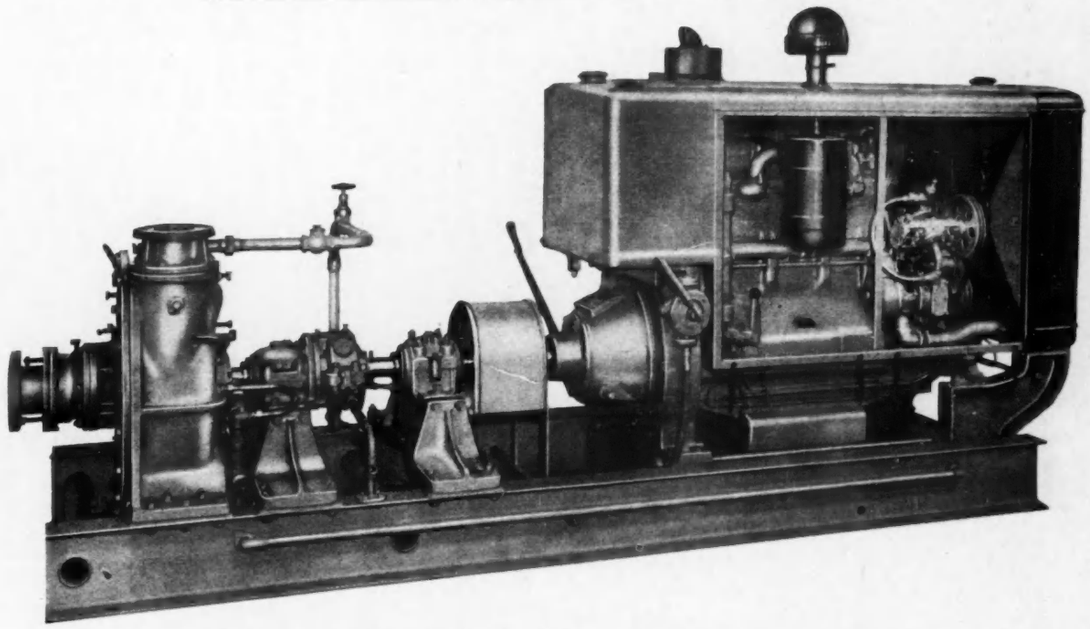

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Completely Hydraulically operated, fully slewing from 5 to 10 tons

* *Illustration shows 5 ton "Hydrocon Highlander" in operation.*

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- No clutches, no electric motor.
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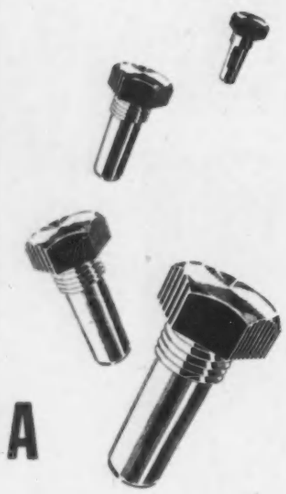

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★ *a view of the cab showing the seat control unit.*

The Adamson 50/10 ton crane is the third of a series of new design supplied to Richard Thomas & Baldwins Limited, Ebbw Vale Section. Features of the crane include monolithic construction of the crab and the elimination of castings by mild steel fabrication of the hoist barrel and bottom block. The cab is of particular interest as it incorporates the most modern type of seat unit ensuring maximum vision and ease of control. Joseph Adamson electric overhead travelling cranes can be supplied to all specifications including cranes suited to the most exacting 24 hours-a-day process work.

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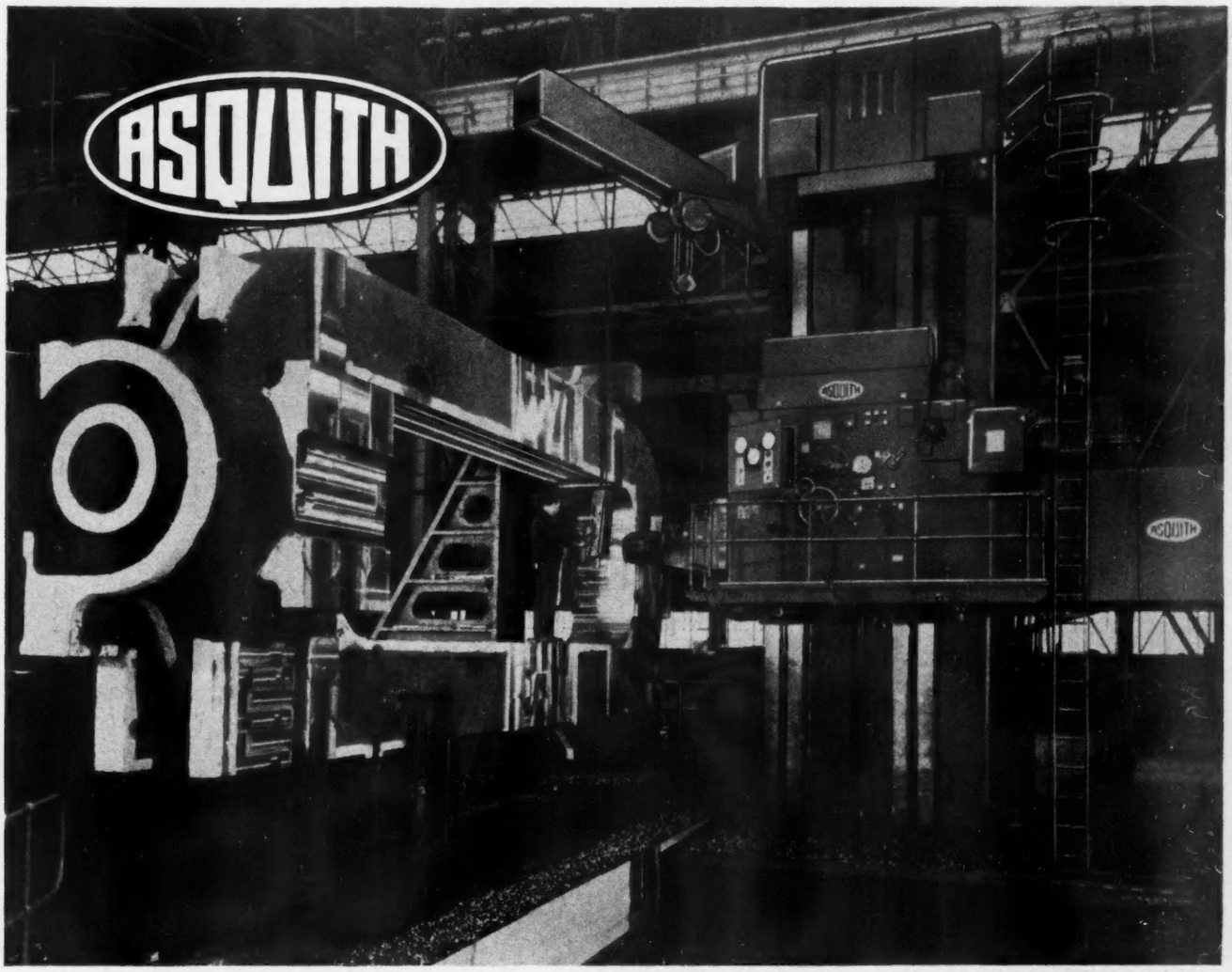

RAM TYPE *Horizontal Milling & Boring Machine at* DAVY-UNITED

The 10 in. Spindle Ram Type machine shown above is machining a 170 ton Mill Housing at the Darnall Works, Sheffield, of Davy and United Engineering Company Limited.

The exceptionally robust proportion of this Asquith machine can be appreciated from the illustration. A 28 in. by 36 in. ram houses the milling sleeve and spindle, both of which travel with the ram. The milling sleeve which carries the cutter is 23 in. dia. and attachments for right angle milling, etc., are also available for heavy duty work. Surfacing slides are available and when fitted obtain feed and hand adjustments from the slide of the machine, thus having all the features of built-in facing heads.

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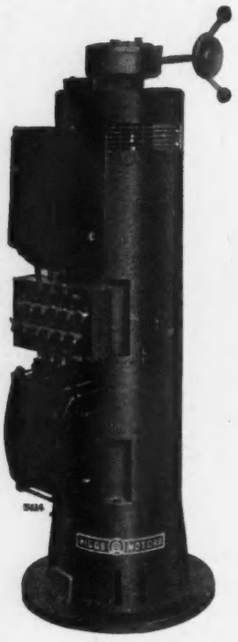

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Maximum output up to 75 kVA

For all occasions where :—

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This organisation is equipped and staffed to carry out initial geological surveys and technical investigations to determine suitable ore dressing techniques.

We design, supply and instal complete ore dressing plants, including those for non-ferrous utility minerals, of all capacities together with the necessary ancillary operating equipment.

This equipment is manufactured by such well-known Czechoslovak enterprises as the Skoda Works, the CKD, The Prerov Engineering Works and the Hron Engineering Works, etc.

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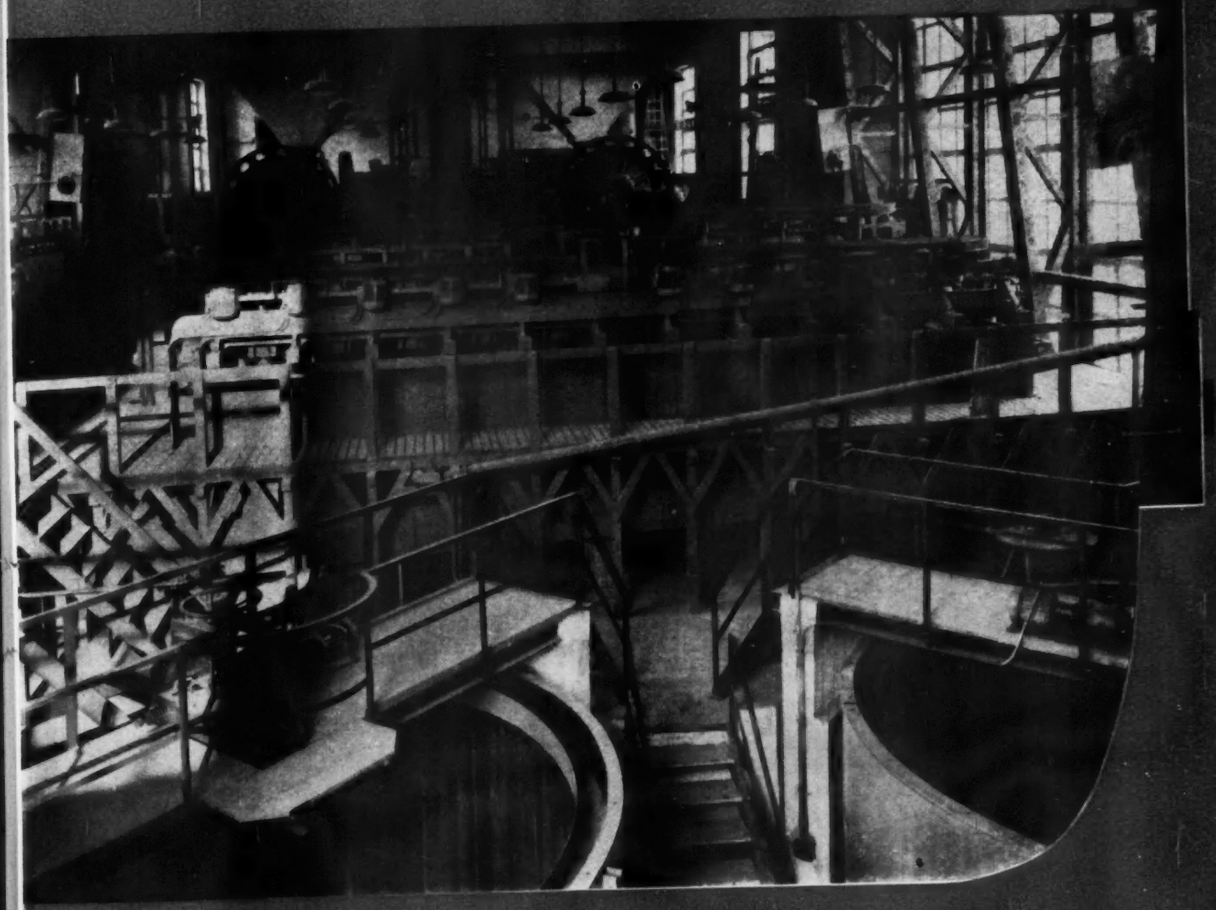

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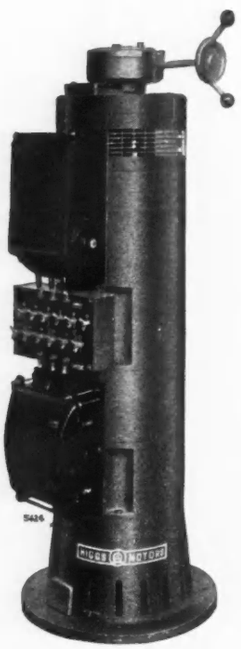

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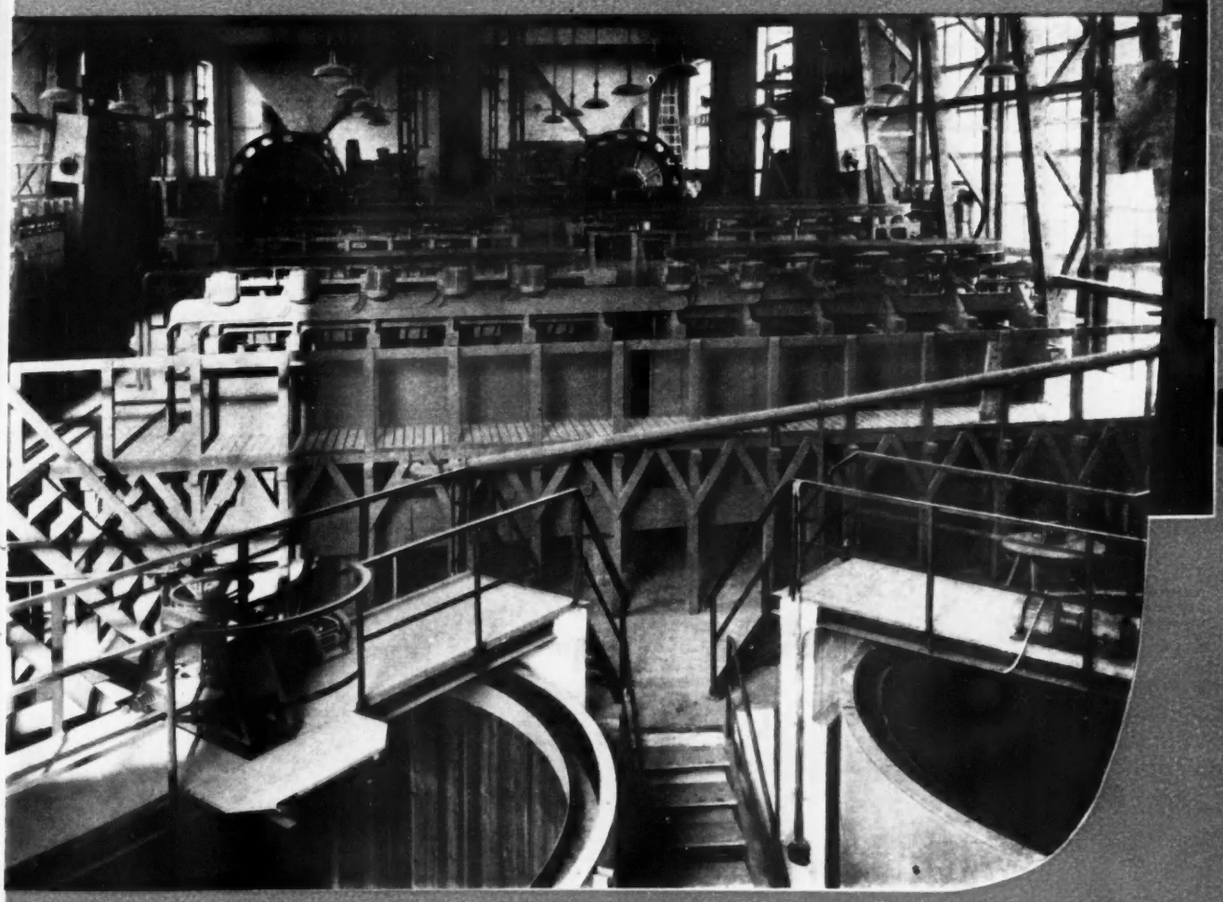

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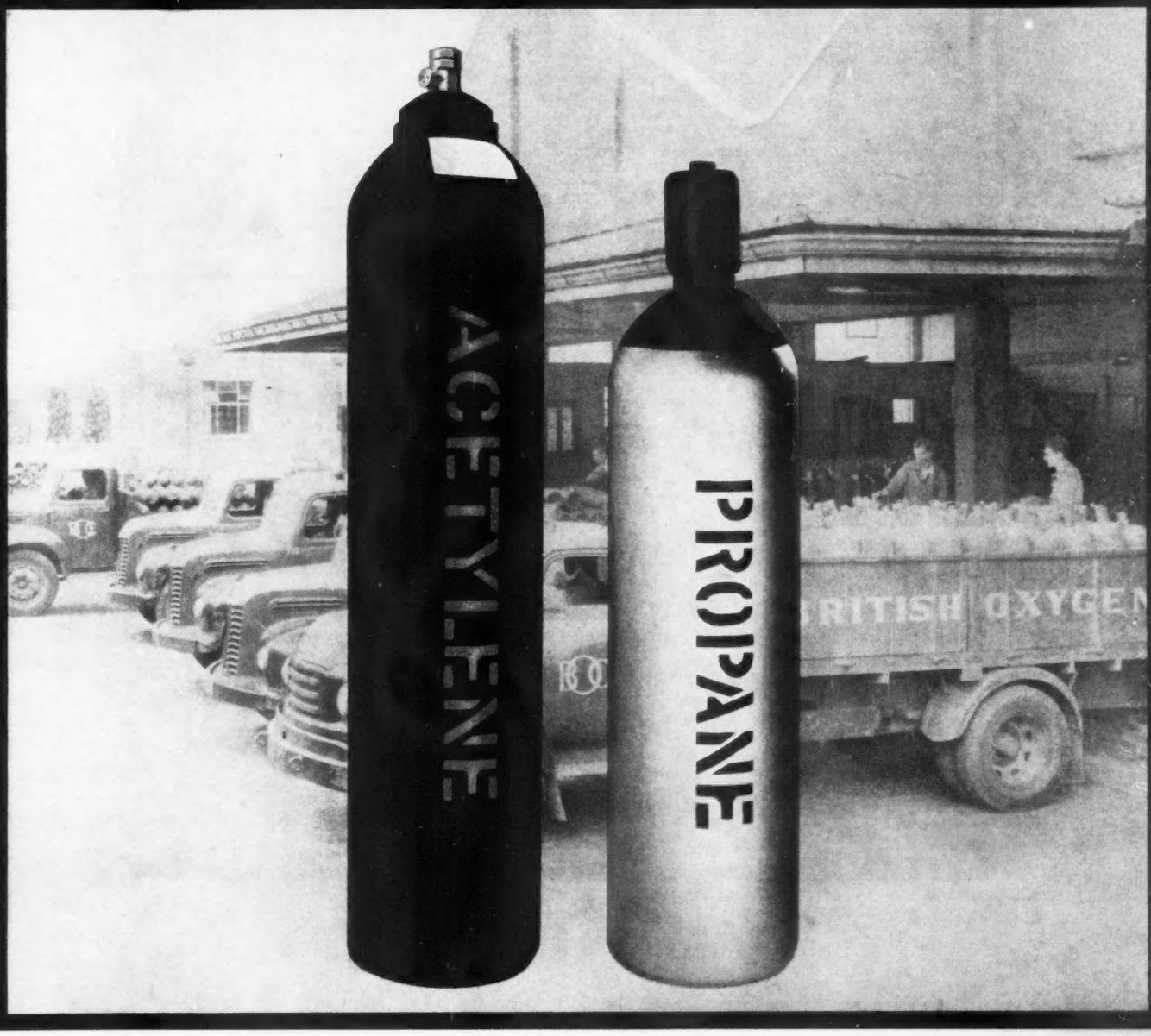

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for quality castings

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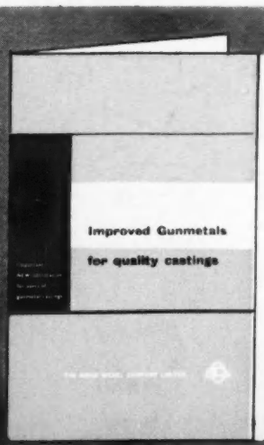

Please send me a copy of your booklet on 'Improved Gunmetals for Quality Castings'.

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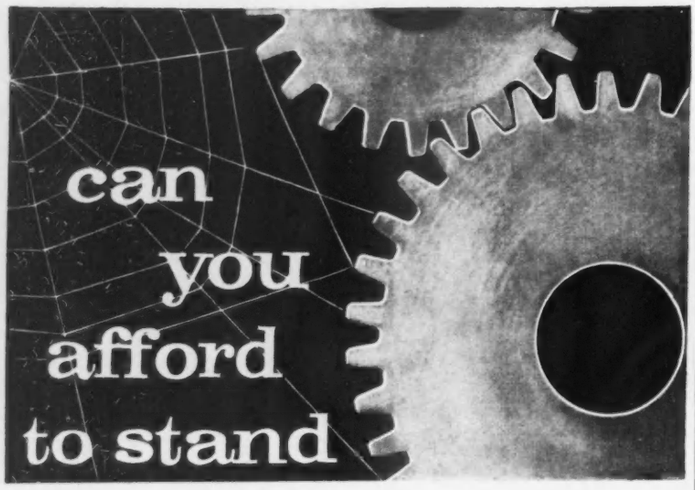

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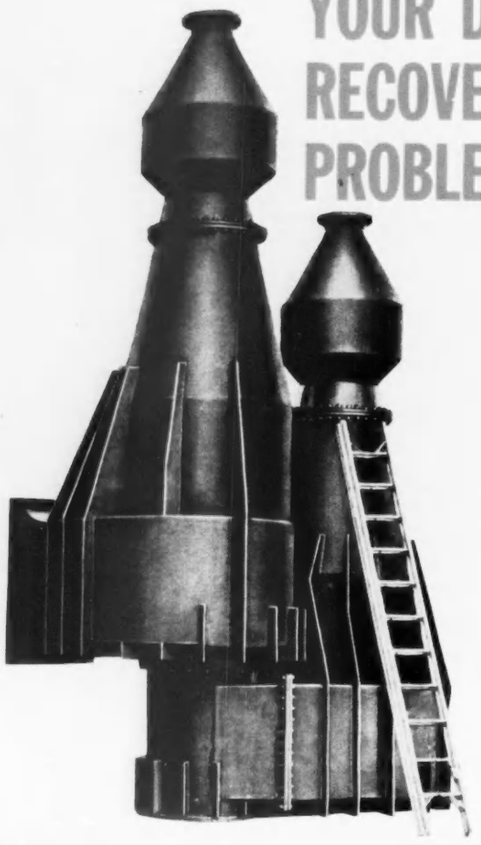
HOW TO SOLVE YOUR DUST RECOVERY PROBLEM



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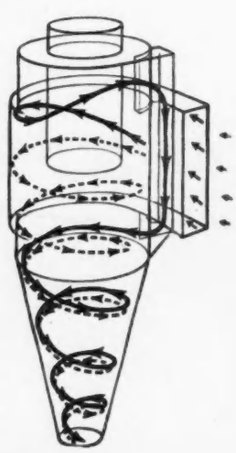

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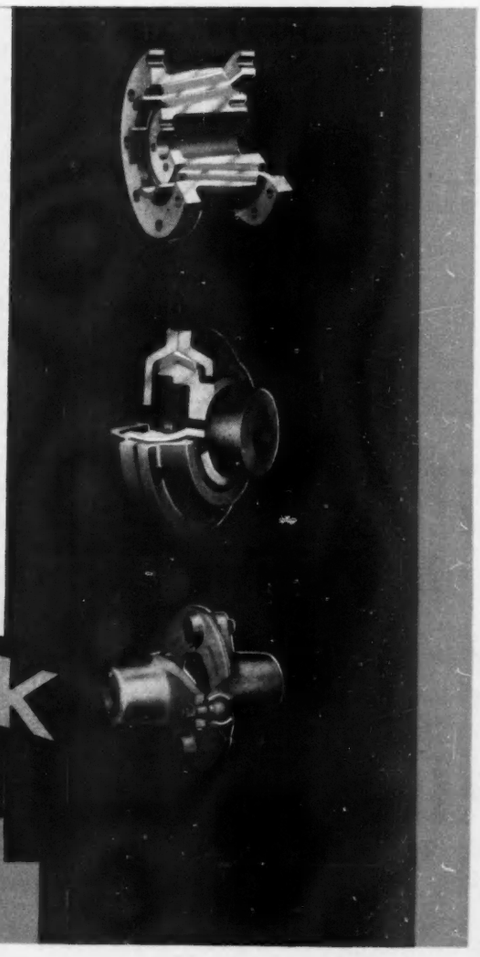

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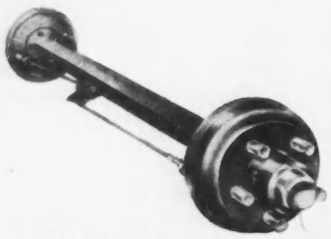

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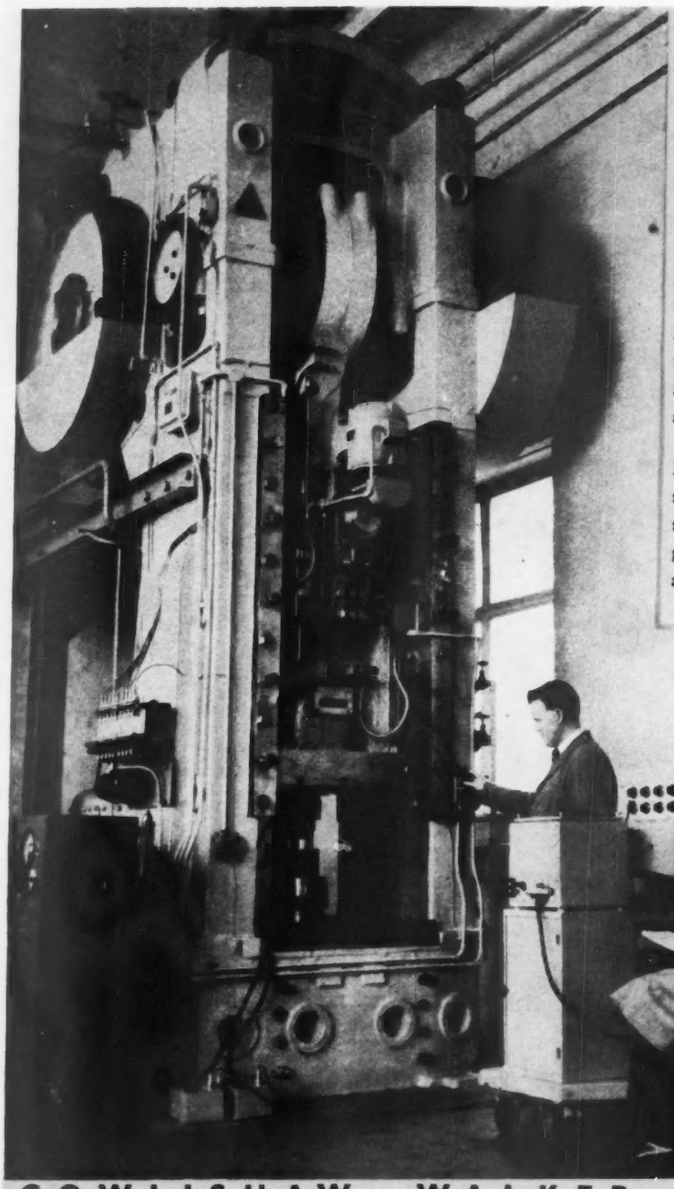

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The precision and absolute dependability of a Cowlishaw Walker press enables exacting research work to be carried out at the National Engineering Laboratory of the Department of Scientific and Industrial Research, at East Kilbride.

In industry the same sterling qualities of Cowlishaw Walker presses guarantee better pressings and much longer tool life.

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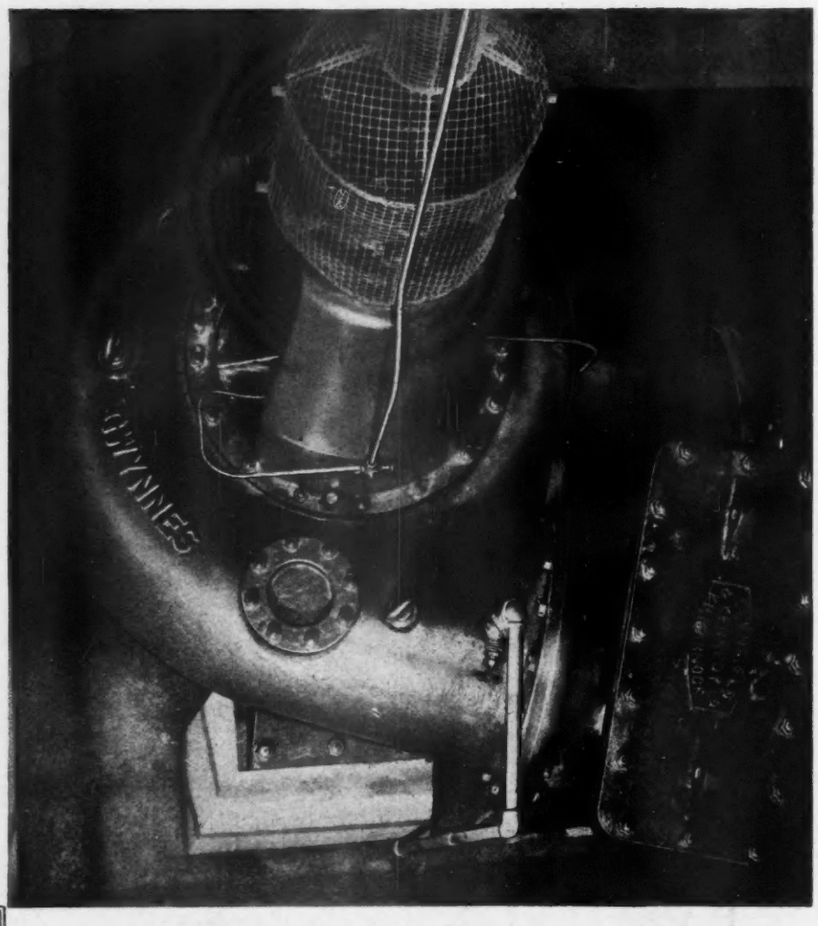
Sewage and Storm Water Pumps

from 3″ size upwards

The photograph shows a 16″ vertical spindle storm water pump supplied to the Borough of Taunton.



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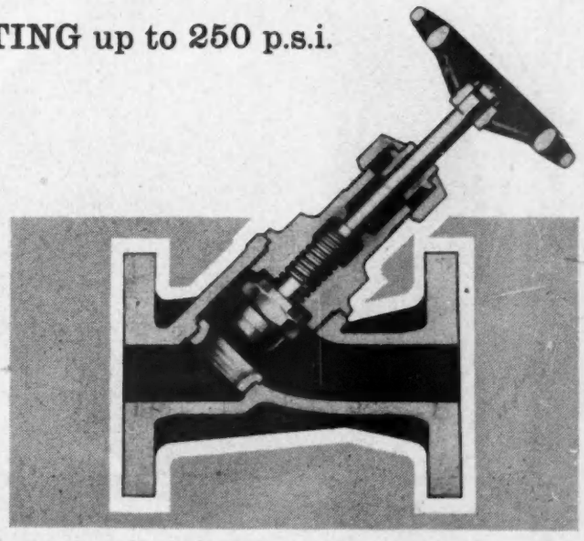
For HIGH PRESSURE HOT WATER HEATING up to 250 p.s.i.

Notable features of design.

1. Cast gun metal body and cover for strength and corrosion resistance.
2. Heavy construction with strengthening ribs scientifically designed to distribute stresses away from the shut-off zone.
3. 'Y' design ensures minimum flow resistance.
4. Renewable disk and seat are made from different nickel alloys for long trouble-free life.
5. Aluminium Bronze spindle with provision for repacking gland under pressure if necessary.
6. Extra wide and deep gland chamber packed with special braided and graphited asbestos block rings.
7. New Design Handwheel for comfortable and effective operation.
8. Available with Double Regulating Device for proportionate control of flow at all settings.
9. **Fig 1200 also suitable as a general purpose steam stop valve.**

There are 3 models of this valve in sizes from ½ in. to 2 in.
1. Fig 1200 GM 'Y' Type Stop Valve. 2. Fig 1200R GM 'Y' Type Regulating Valve. 3. Fig 1200 DR GM 'Y' Type Double Regulating Valve.

Please write for the brochure in which they are described and illustrated.



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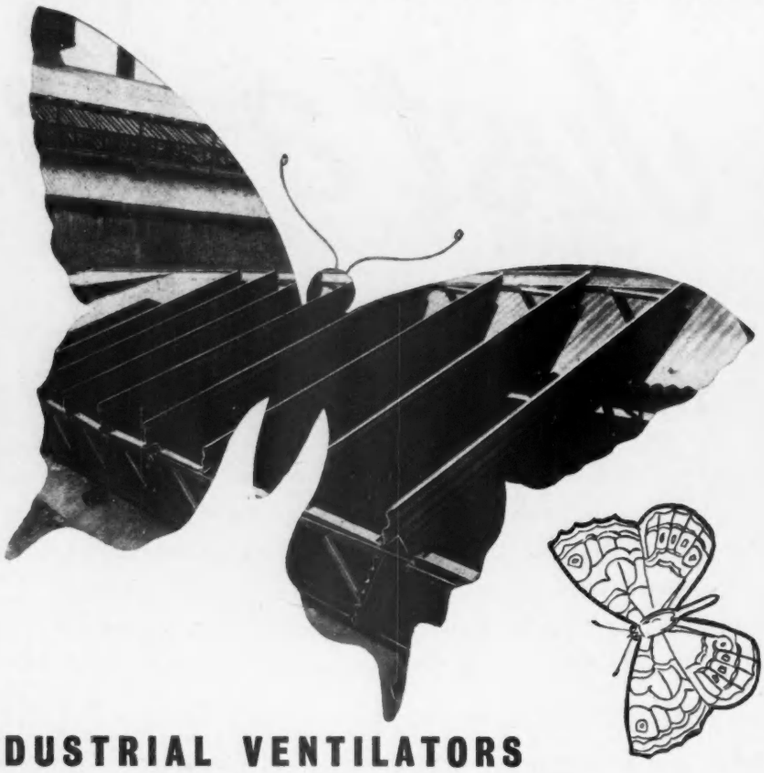
Full information from Hills technical department



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Branches at: Manchester, Bristol, Newcastle-on-Tyne, Glasgow.

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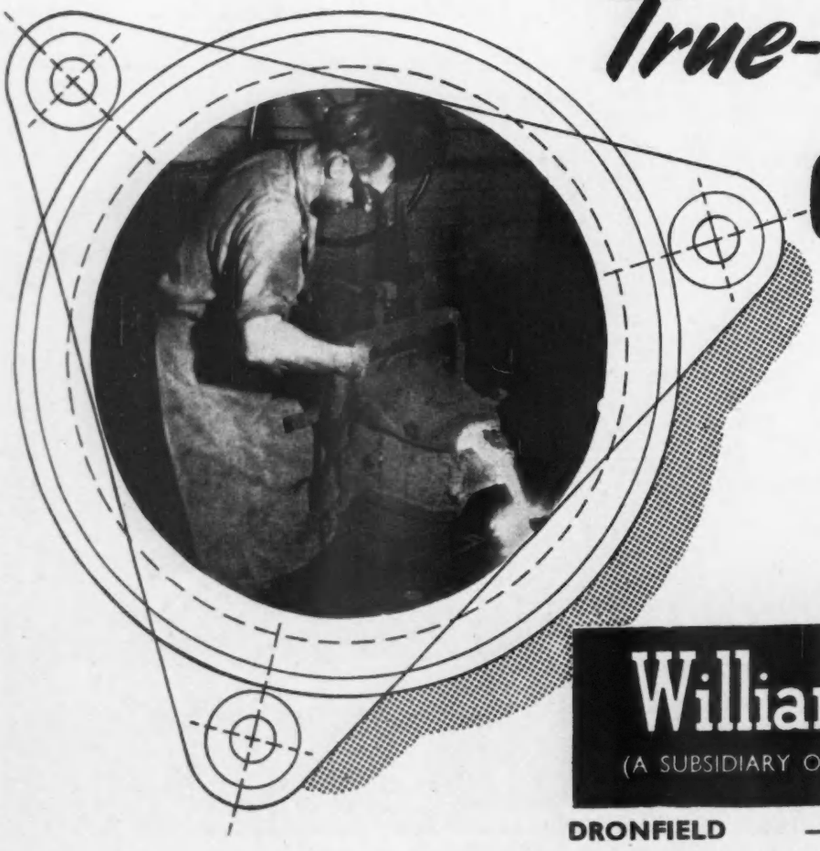

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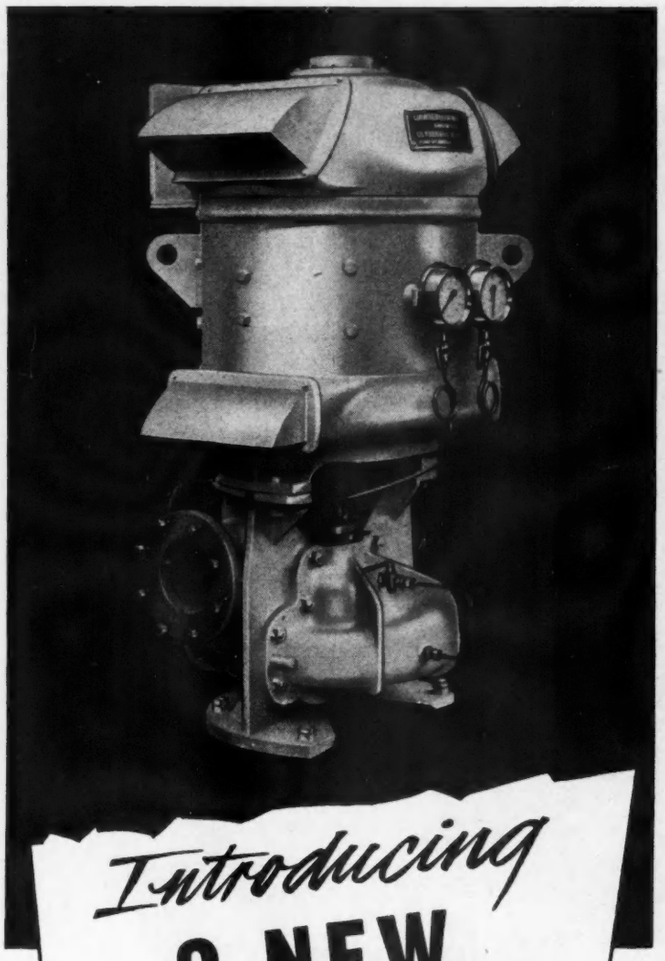

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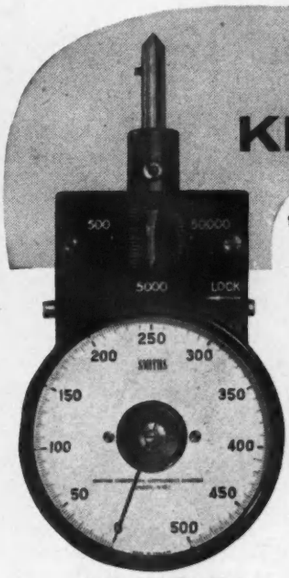

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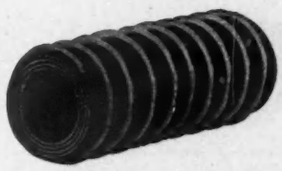

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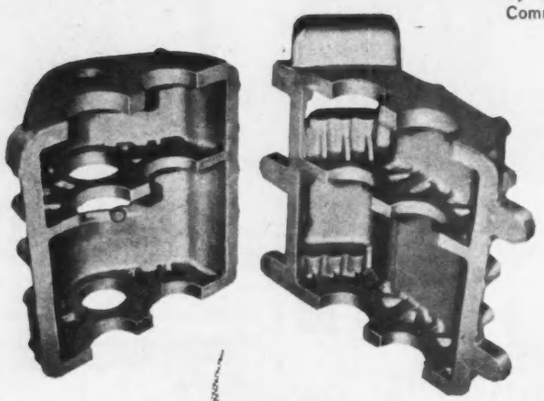

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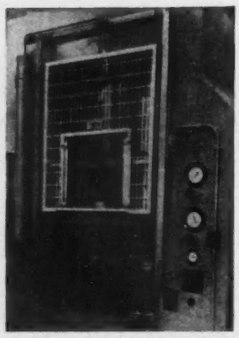

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first for
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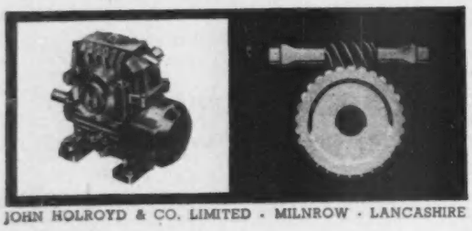

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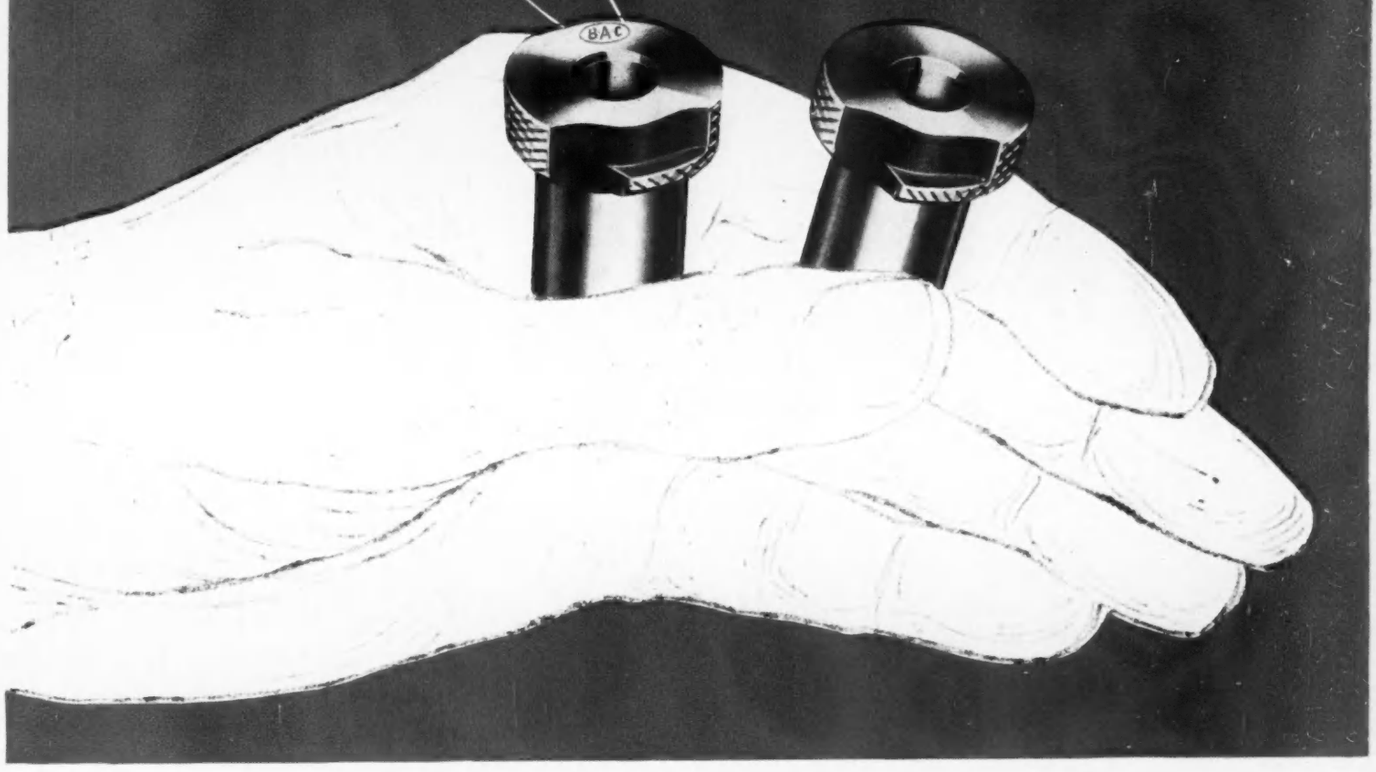

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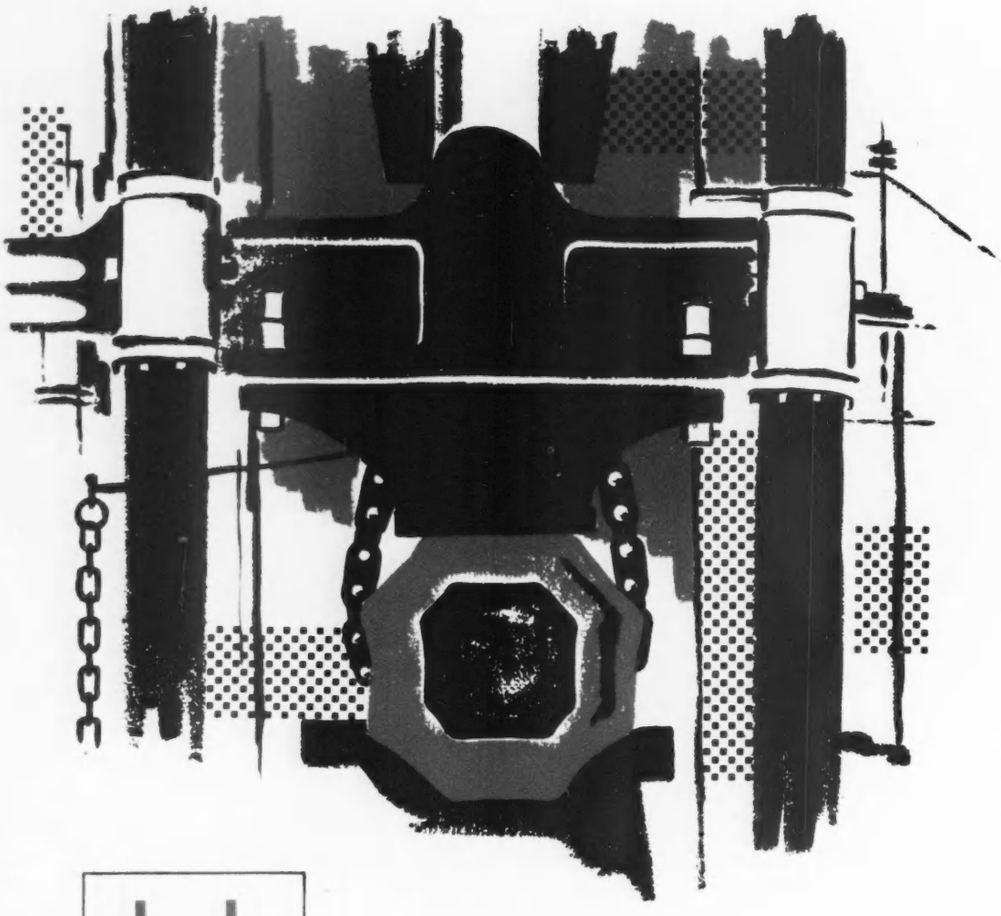

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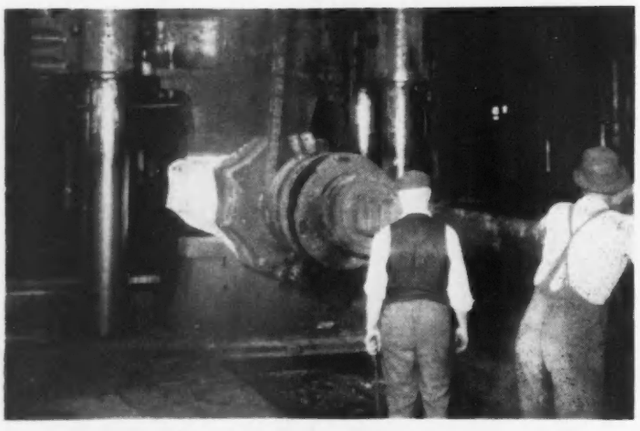

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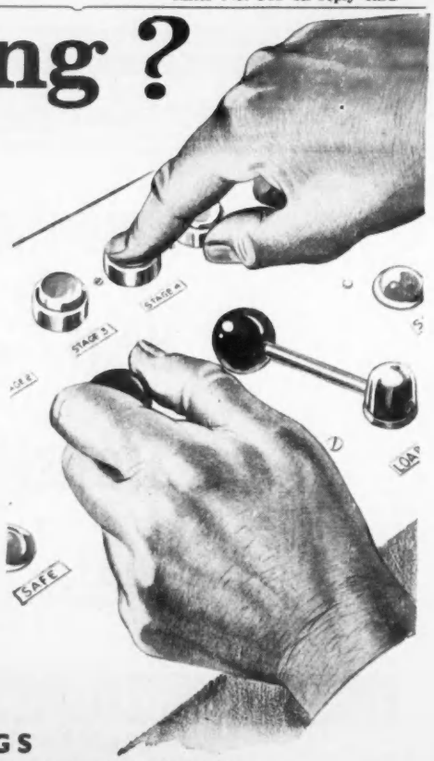

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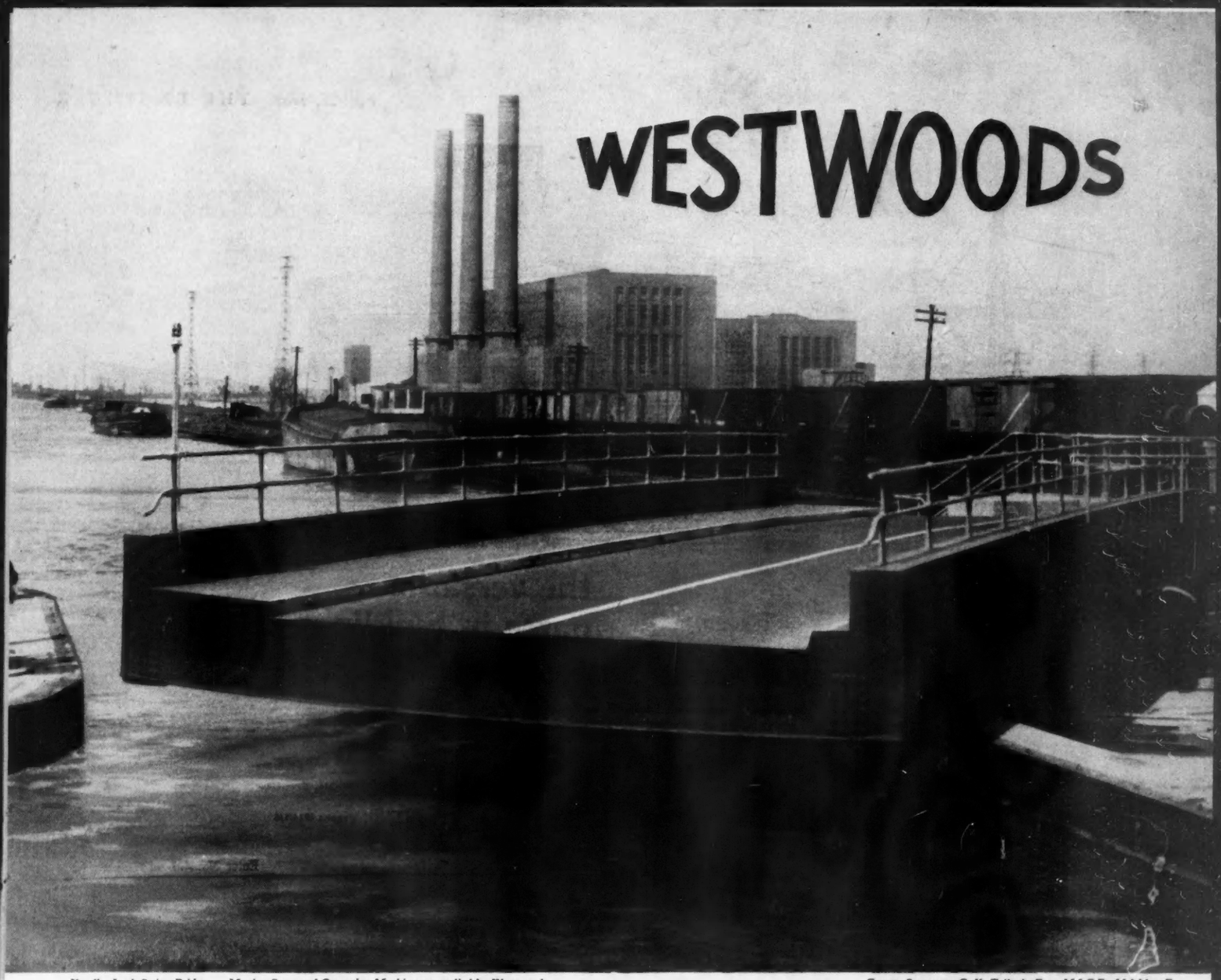

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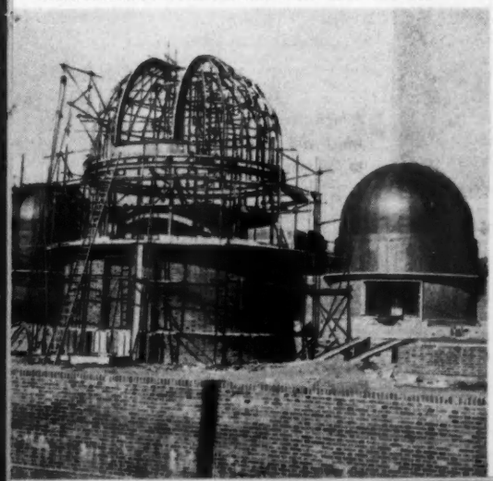

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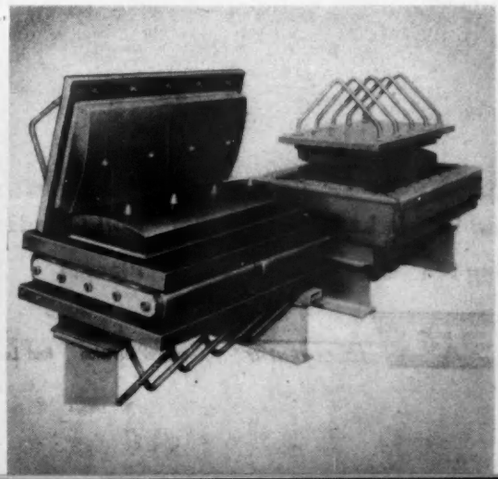

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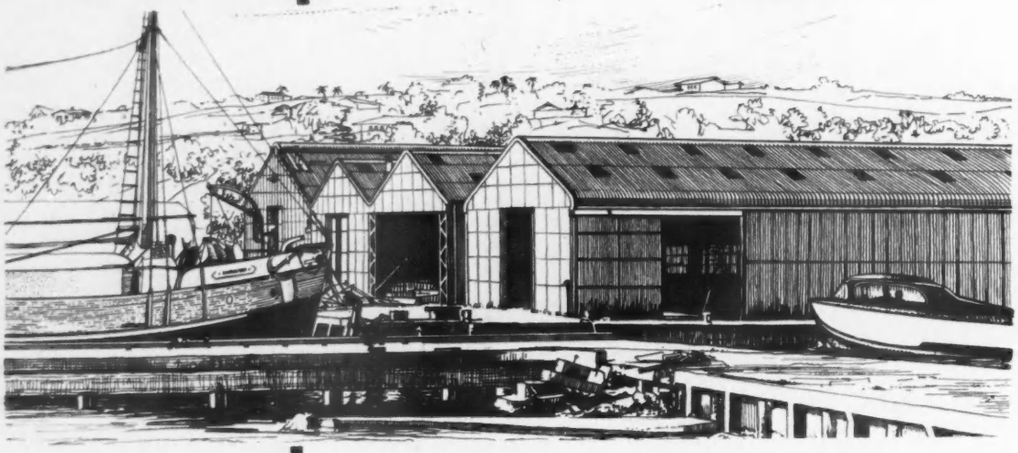

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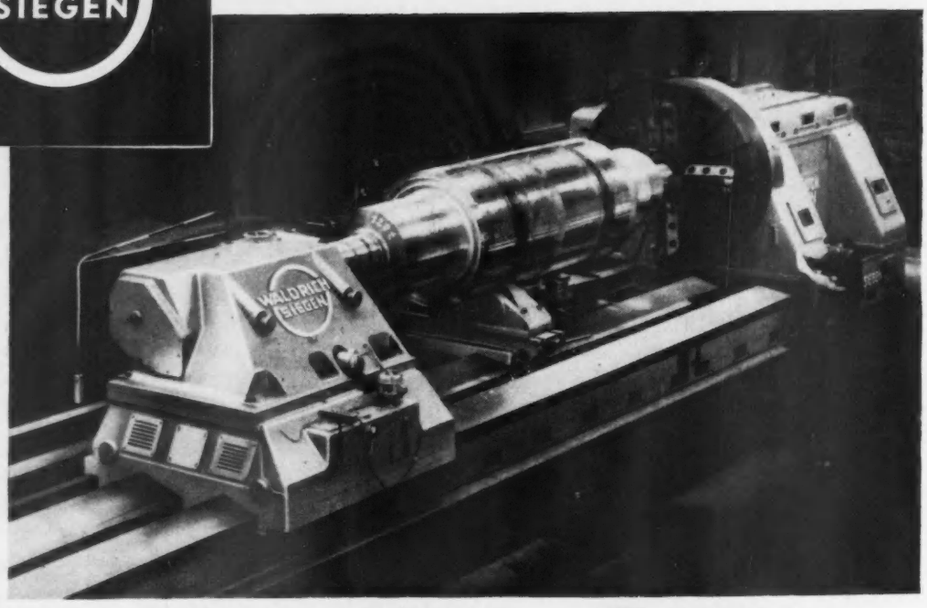
HEAVY-DUTY MACHINE TOOLS



H. A. Waldrich of Siegen, Germany, have designed and built various types of heavy-duty machine tools for over 50 years. These machines are extremely rugged and highly efficient in production.

A high-speed, heavy-duty lathe which will take workpieces up to 130 tons in weight.

- High-Speed, Roll Turning and Facing Lathes
- Combined Planing and Milling Machines
- Roll Grinders
- Planers

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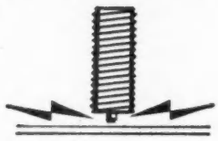
OMARK® | GRAHAM®

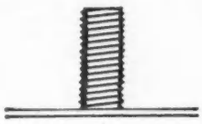
STORED-ENERGY

Stud Welding System

RAPID, EFFICIENT, ECONOMICAL STUD WELDING FOR MANUFACTURING AND CONSTRUCTION USE



1. A low voltage, high amperage electrical discharge through the patented OMARK-GRAHAM stud tip initiates arc, melting stud face and area of contact on work piece.



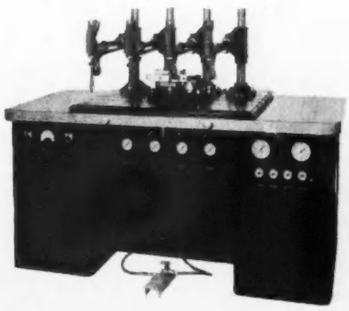
2. The stud face is pressed into the molten contact area, forming a strong weld without distorting the workpiece, burning its opposite side, or otherwise damaging it.

The OMARK-GRAHAM system of stud welding combines the advantages of resistance and arc welding to fasten small studs or pins to thin metal without burn-through or distortion. No flux, ferrules or inert gases are required in the process, which welds low-carbon ferrous and many non-ferrous metals: steel, stainless steel, copper, aluminum, zinc. The reverse side of metals to which the studs are welded may be painted, plated, enameled, or coated with ceramics, plastics or other materials.

WELDING EQUIPMENT FOR MANUFACTURERS

MODEL 2000 MULTIPLE-GUN BENCH WELDER

Welds studs up to ¼" in diameter. Available with one to four guns, individually adjustable to meet requirements. Manual control, generator actuated.



MODEL 3000 BENCH WELDER

Welds studs up to ¼" in diameter. Manual control, generator actuated. Full safety equipped and guaranteed by manufacturer.

TYPICAL OMARK-GRAHAM STUDS

A wide range of studs designed for numerous standard applications are available.

CUSTOM WELDERS AND STUDS

OMARK-GRAHAM designs and manufactures welding equipment and studs or pins to meet customer specifications. Design and engineering counsel is available on request.

SUGGESTED APPLICATIONS

MANUFACTURING: Name plate and instrumentation paneling • electric appliance • surgical equipment • automotive and aircraft assembly • radio and television equipment • Kitchen, lavatory and tavern appliances. **CONSTRUCTION:** Suspended ceilings; roofing, siding fastening • tank, duct and heating insulation • metal wall and panel fastening.

Appraise **your** needs: if two metal parts are to be joined, OMARK-GRAHAM stud welding can serve you faster, better, more economically.

For details contact our European representative, Otto J. Kilsdonk, during February or March at 52 Prins Bernard Laan, Voorburg, Z-H, The Netherlands, or write air post to

INTERNATIONAL DEPARTMENT

OMARK Industries, Inc.

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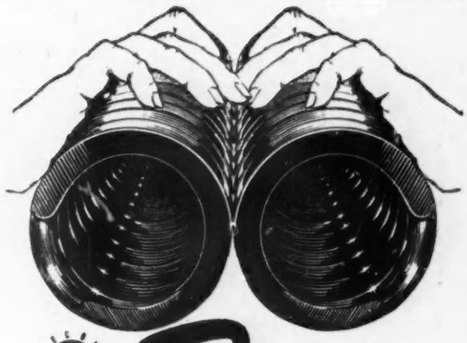
Looking in the right direction



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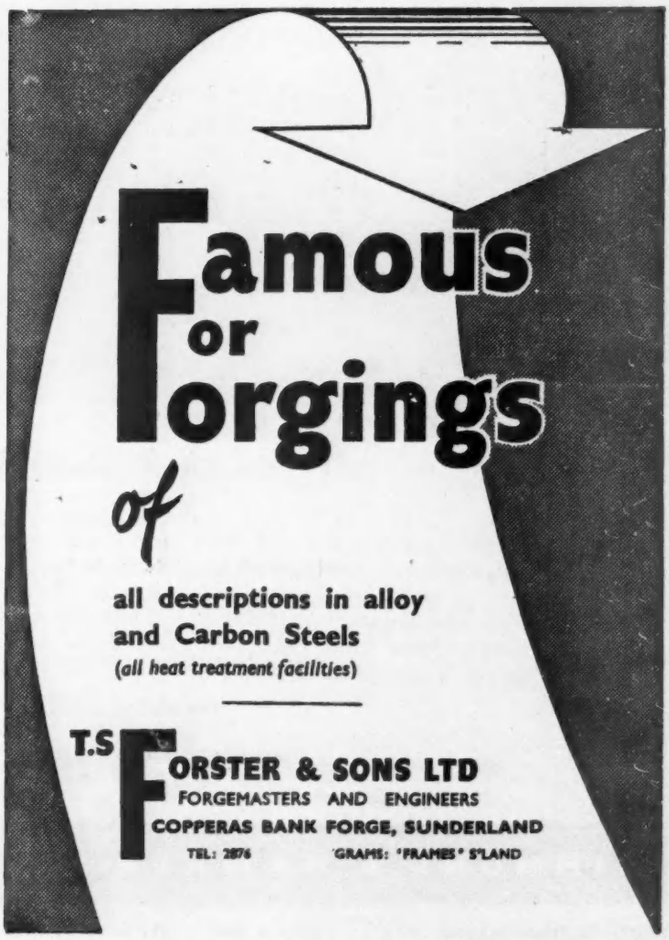

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72" High 34" Wide 12" Deep

- Brand new—Manufactured in our own Works.
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- Stove enamelled dark green.
- 6 shelves per bay—Extra shelves 8/- each.
- Quantity discounts.
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- All other sizes available at equally keen prices.

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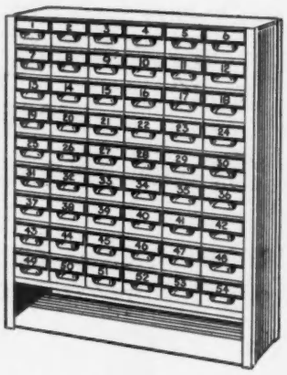
All-steel, stove enamelled dark green

Our most popular unit, with 54 drawers, each 5" wide, 3" high, 11¼" long, each drawer fitted with 1 free divider and drawer card. Extra dividers can be obtained at 6d. each. Cards supplied free. Overall size of unit, 42" high, 36" wide, 12" deep.

* *Send for SAMPLE DRAWER without obligation.*



£18. 0. 0. delivered free to England, Scotland and Wales

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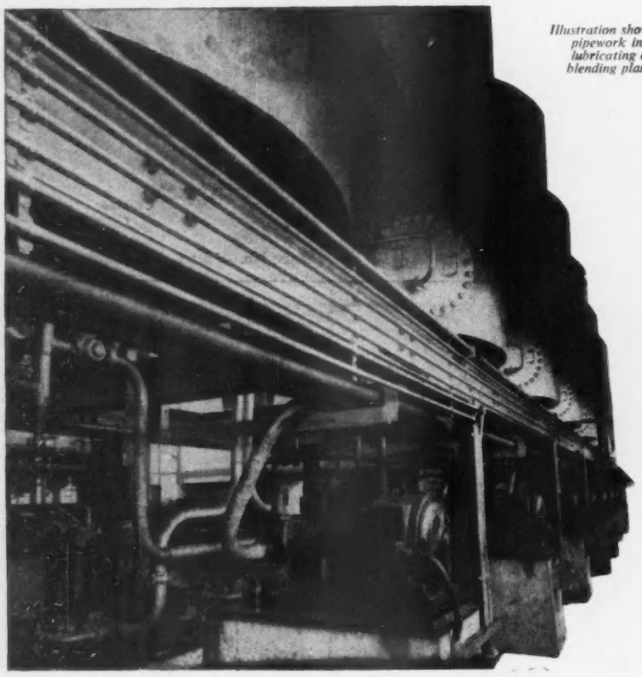

Illustration shows pipework in a lubricating oil blending plant.

Branches everywhere

Mains, branches, auxiliaries—the lot.

However complex

your pipework requirements may be,

we can plan, fabricate and erect

exactly the installation you need.

Our advisory service

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a non-metallic bearing

suitable for heavy applications

Illustrated here is a large trunnion bearing we have produced for a ball mill. The bearings liners—nearly three feet in diameter—are of Paxolin laminate and fit into cast steel housings.

Paxolin bearing are shock resistant and with water lubrication, or immersed in water, can be used where grit or sand is unavoidable or where occasional but reliable functioning is required. Bore hole pump shafts, rolling mills, rudder and stern shaft bearings are a few examples of the many applications for Paxolin bearings. "Paxolin" serves so many purposes so well.

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"Paxolin" is a registered trade mark.

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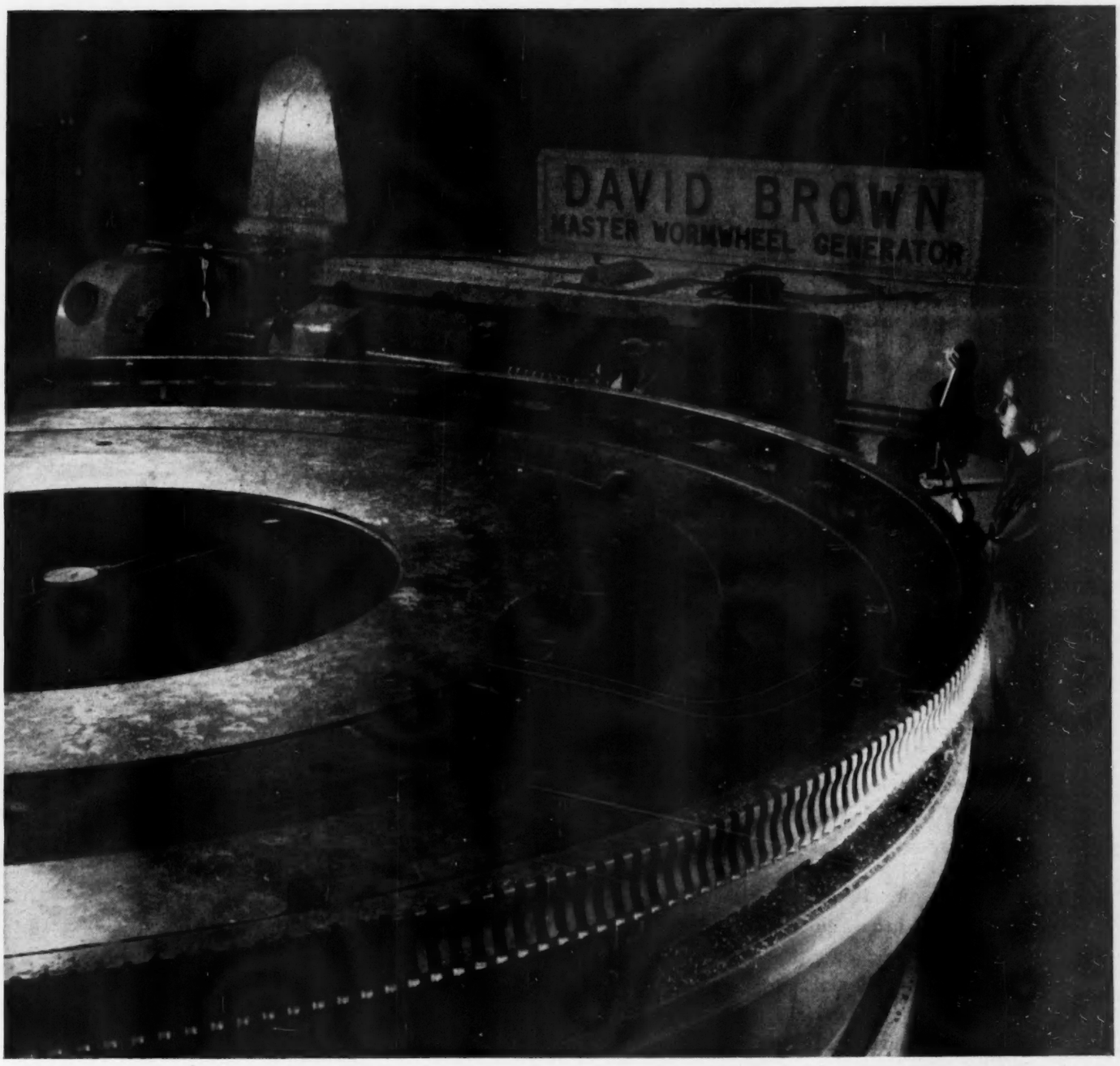

A matter of breeding

The production of large diameter master gears is a process of continuous research, development and breeding. The accuracy of David Brown gear-cutting machine tools has been achieved by the systematic production of master gears one from another, each being produced to finer limits than its predecessor.

The David Brown Machine Tool Division was the *first* firm in the world to produce a Master Worm Wheel Generator exclusively for the production of worm gears for turbine gear-cutting machines.

As they also make *more* turbine gear-cutting machine tools than anyone else, it follows that David Brown machine tools are the finest and most accurate of their type in the world.

DAVID BROWN

An alliance of engineering specialists in gearing, machine tools, castings, automobiles and agricultural tractors and machinery.

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are embodied in the latest range of
ELSTREE Worm Reduction Gears by
S. E. OPPERMAN LIMITED.

Almost a century of experience in the design and manufacture of Power Transmission Equipment is packed into every ELSTREE Gear Box. By constantly anticipating the needs of Industry, S. E. OPPERMAN LIMITED have always maintained their lead as specialists in this field. Now, with a new design range, new standards of reliability and performance, and the backing of a nation-wide Technical Sales Force, they are able to offer unequalled service and to provide a range of Units to cover all conceivable applications.

The Worm Reduction Gear Box illustrated has been specially designed for liquid agitation. Features of this Box are wide spacing between bearings to allow for long unsupported impeller shafts and a bottom bearing specially designed to prevent oil seepage down the shaft. Further details on request.

ELSTREE dependable WORM REDUCTION GEARS

Whatever the nature of your problem, we shall always be happy to advise you on the most efficient transmission installation at the most economical cost. Please write or telephone our Sales Director for immediate attention to your enquiries.

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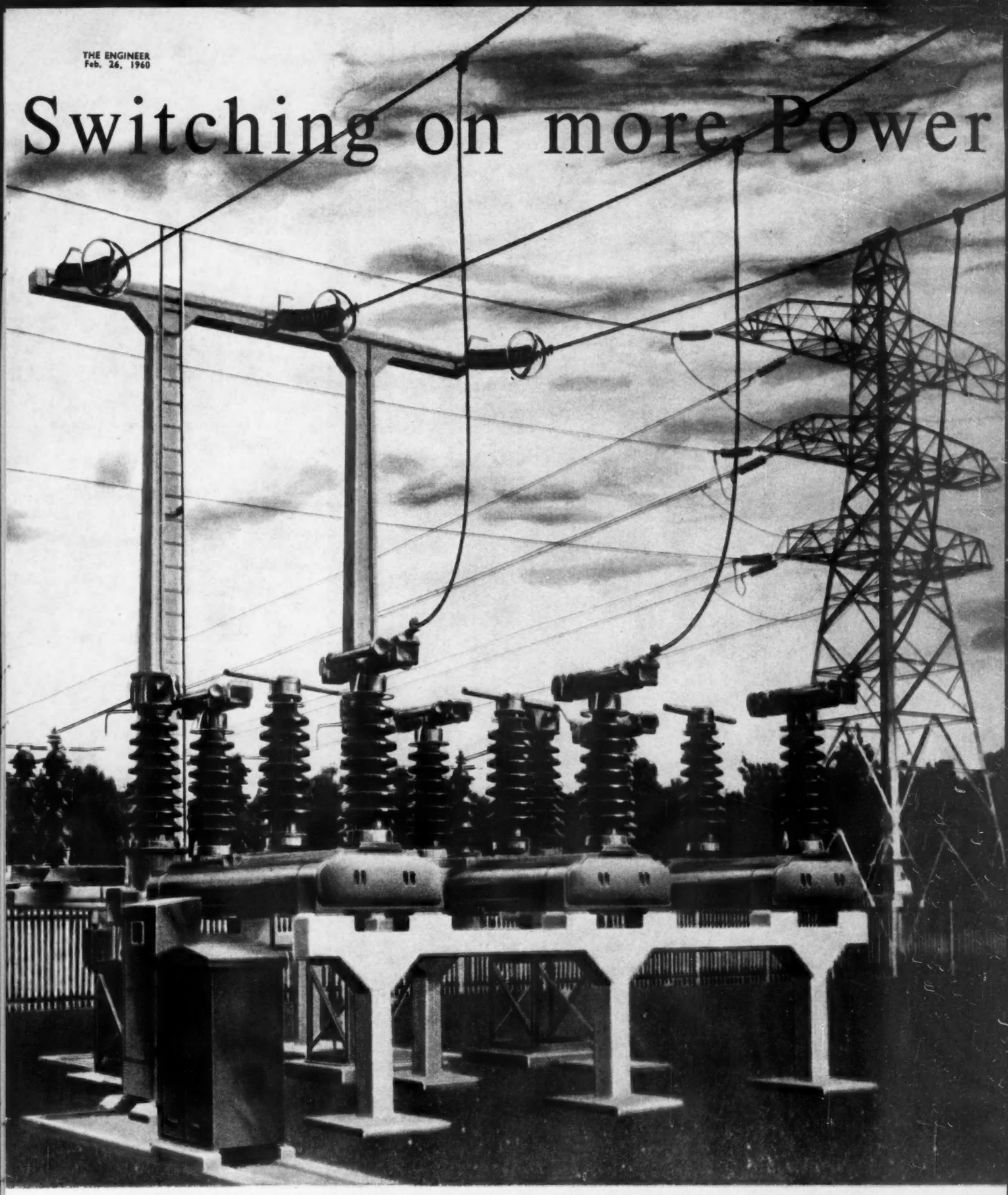
Switching on more Power



The photograph shows a 132 kV., 3,500 MVA., Type GA6W4 Air-Blast Circuit Breaker installed in a British substation

This type of breaker is in extensive use on the British grid system, and has been selected to control the output of Scotland's first Nuclear Power Station at Hunterston. Overseas, 132kV., 5000-MVA., Type GA6W4 breakers will be installed in seven new sub-stations in the Greater Buenos Aires area of Argentina.

Associated Electrical Industries Limited
SWITCHGEAR DIVISION

Trafford Park, Manchester · Higher Openshaw, Manchester · Willesden, London

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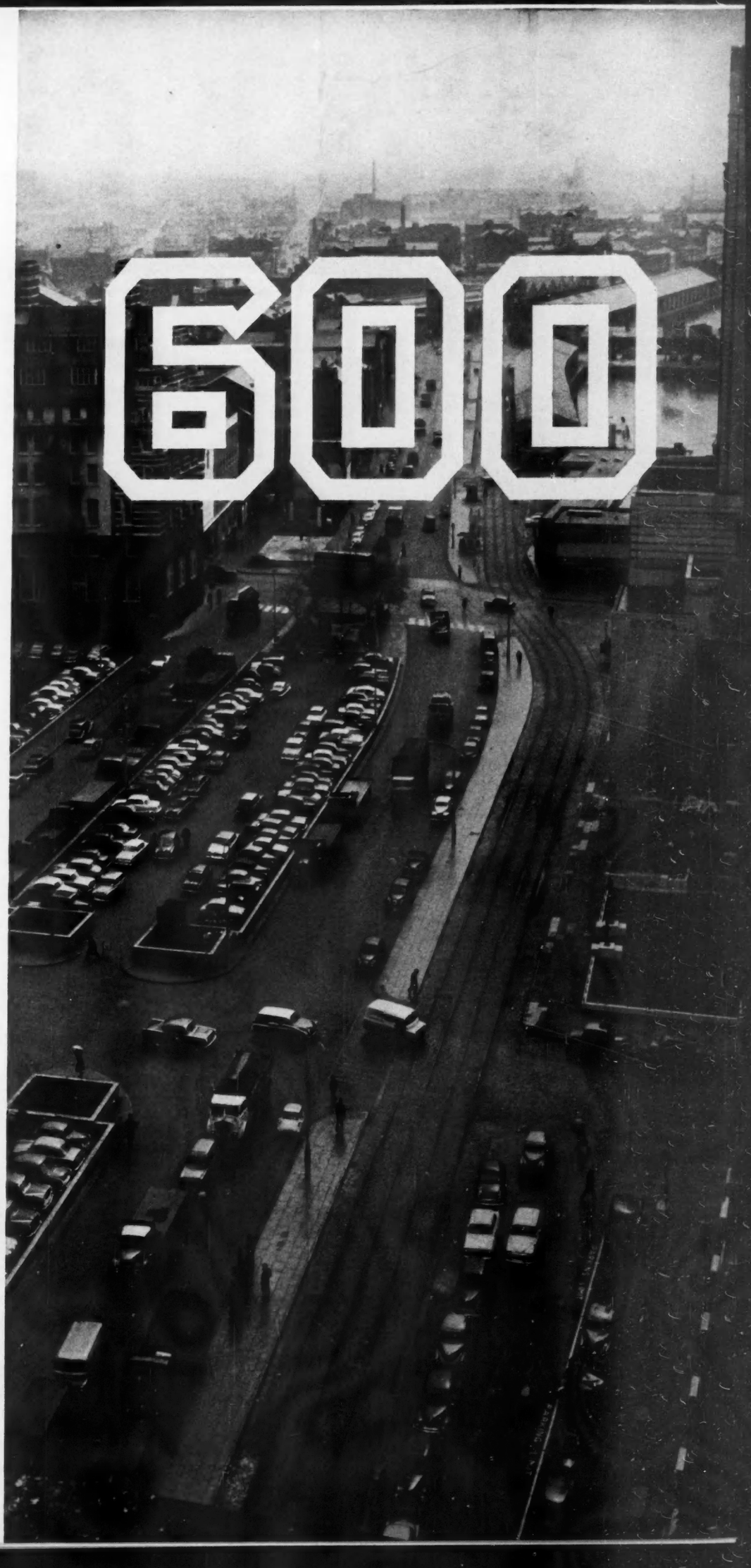
Dismantling

Six-and-a-half miles of Liverpool Overhead Railway. 25,000 tons of iron and steel to be removed without impeding the dockland's vital arteries. Now that the last of the massive stanchions and columns and bridges have gone, a new scene emerges. Yet another major achievement by George Cohen.

THE 600 GROUP OF COMPANIES

by 600



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'Trilac' dipping and vacuum cleaning department of the 'CLEAN CONDITIONS' PLANT

S&L PIPEWORK FOR BRITAIN'S NUCLEAR POWER STATIONS

It is becoming general for many components for nuclear plants and other forms of construction to be assembled under entirely dust free conditions.

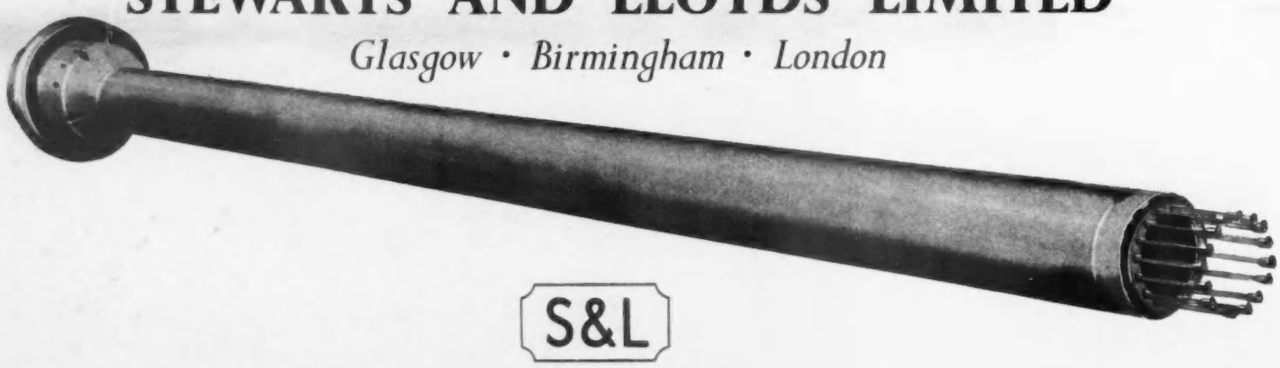
To meet the requirements of the nuclear age S & L have constructed a special 'clean conditions' plant at their Tollcross Works in Scotland. This new plant is probably the largest and best equipped in industry and comprises many important features, including fully filtered and heated air, a large assembly area, together with cleaning and protection facilities.

An example of the work assembled in this shop is the control rod standpipes for Hunterston nuclear power station. The standpipes shown in the illustrations accommodate boron rods and house the small bore burst slug detection piping.

S & L will be pleased to discuss any problems associated with clean conditioning of industrial components.

STEWARTS AND LLOYDS LIMITED

Glasgow · Birmingham · London



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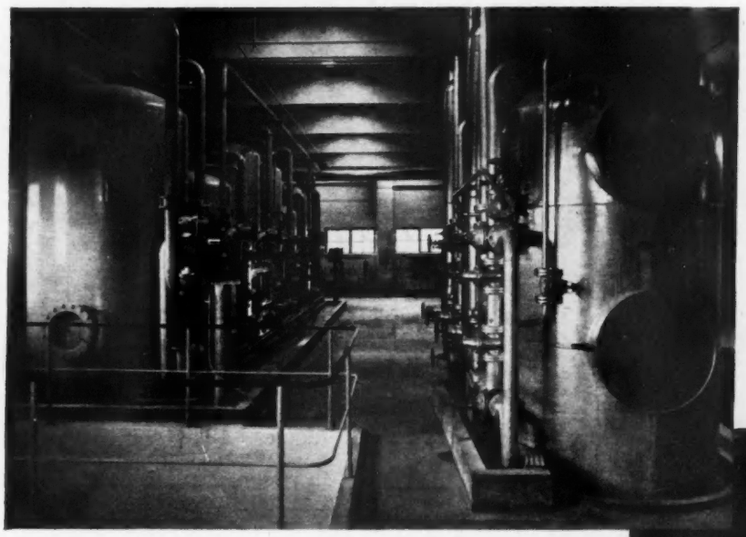
WATER TREATMENT IN FINLAND

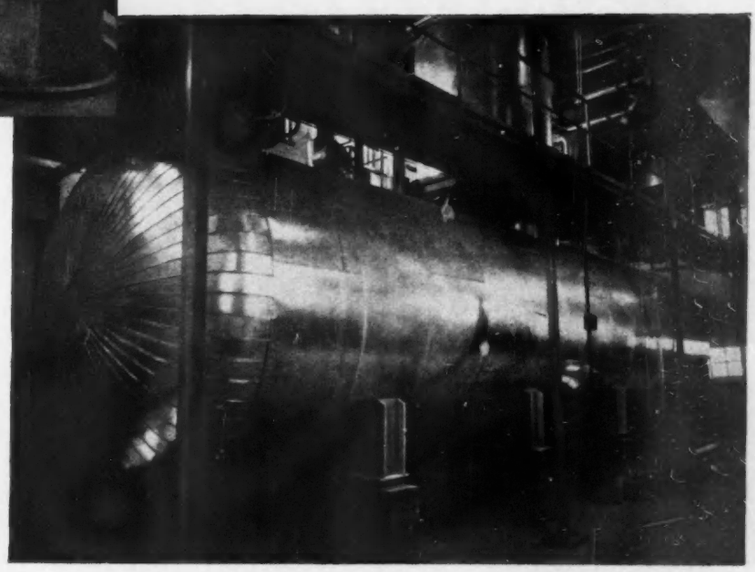
Complete boiler-feed water-treatment plant for the new Veitsiluoto O/Y Paper Mills, Finland

Boiler pressure 1,750 psi, 42% make-up



One of seven similar "Boby" installations in Finland treating highly organic lake-water for boiler feed purposes.
All plant made in Finland to the designs of William Boby & Co.

Demineralisation Plant for Boiler feed make-up, capacity 13,400 g.p.h. and base-exchange softener for condensate returns, capacity 18,000 g.p.h.



Deaeration Plant, capacity 250,000 p.p.h. with 30 minutes storage.

WATER BOBY TREATMENT

Established in 1875

WILLIAM BOBY & CO. LTD.

RICKMANSWORTH, HERTFORDSHIRE, ENGLAND. Tel: Rickmansworth 4251

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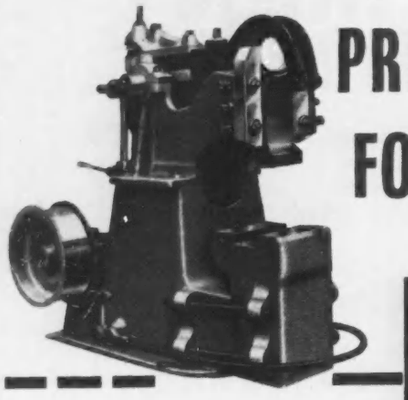
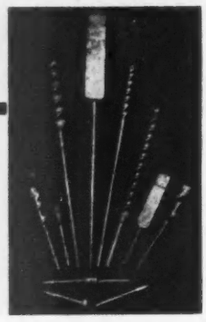
HIGH SPEED-

PRECISION FORGINGS





275/300 blows per minute. Average size of work 1¾" bar. Adjustable stroke and guides. Rubber cushioned overhead motion. Loose Anvil Block. Separate motor stand available. A typical example of the type of work accomplished on this machine (illustrated right). For High Speed Precision Forging—the Model "100" POWER HAMMER.

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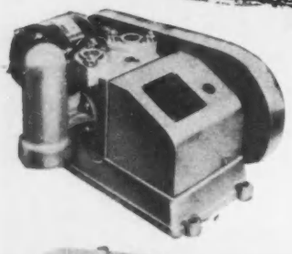
FOR GOOD PUMPS



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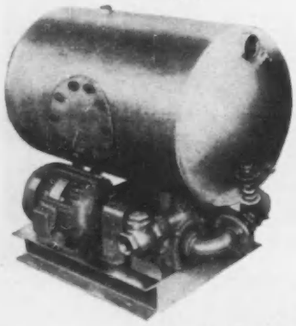
Ideal for service in the many industries where corrosive and abrasive liquids must be pumped. Positive self-priming and can be run dry without harm.

VERTICAL SPINDLE SUMP PUMPS ▶

Automatic pumps designed specifically for sump drainage. Sturdy, self-contained and reliable under the most difficult conditions.



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Outstanding in performance and reliability these ball-bearing centrifugal pumps range in size from ¾" to 5" for continuous industrial applications. Constructed of cast iron or bronze, with smaller sizes in stainless steel.

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Incidentally, the illustration reminds us that there are grades of Aerox porous ceramic material to withstand high degrees of thermal and physical shock.
All the technical literature you need is available. Please write

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BUTTERS

for the Madras Port Trust

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Supplied through our agent Martin Burn Ltd. of Calcutta.
We have always made a special feature of heavy derricks and will be pleased to supply details or quotations.

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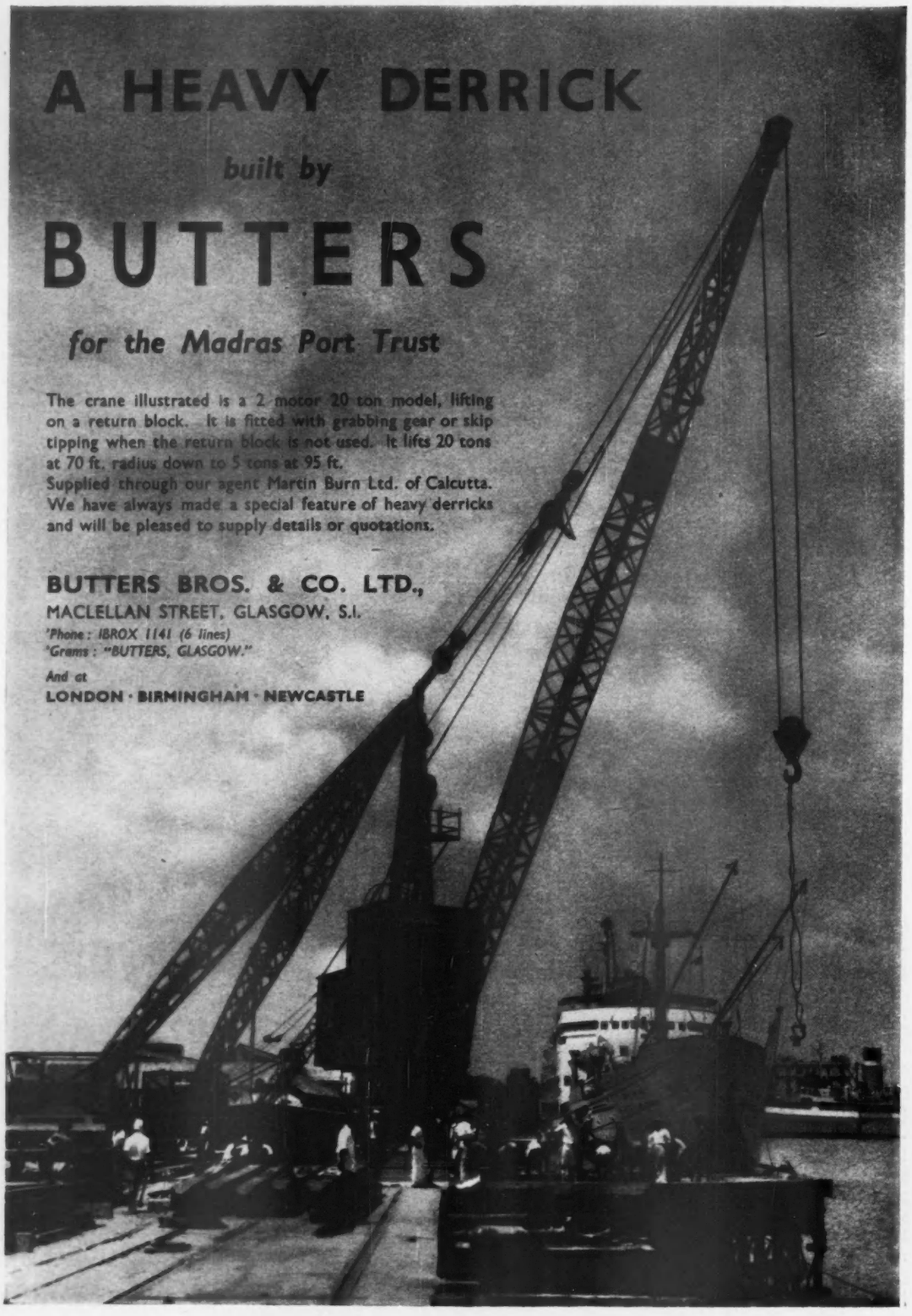

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'DOUBLE MUSHET'
HIGH—SPEED STEEL
TWIST DRILLS

We do not know the number of holes made every day throughout the world by fast-cutting "Double Mushet" drills, but we do know that all of these drills are of consistent top quality. Manufacture throughout within the same organization makes possible rigid production control in inspection, from the melting of the steel to the despatch of the finished product.

★ *Comprehensive stocks constantly maintained*

POCKET DRILL SETS

Four sets of drills are available packed in attractive metal containers of cigarette case size. No more lost drills for the practical engineer and handyman.
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FINE STEEL MAKERS · STEEL FOUNDERS · ENGINEERS' TOOLMAKERS

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  - Immediate delivery
  - Cut lengths or randoms
  - In most diameters and thicknesses
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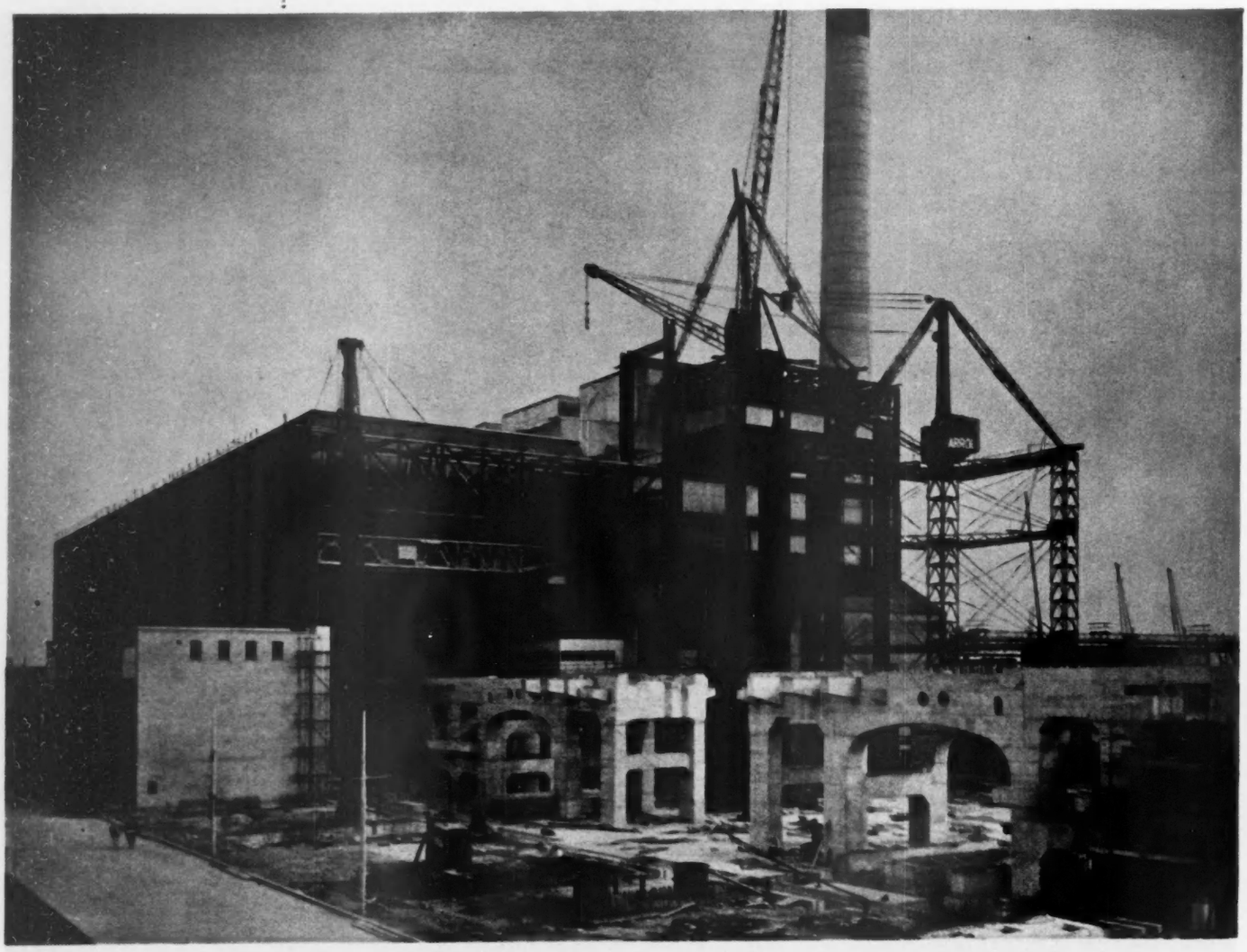

Steelwork for Power Stations

Throughout the country steel-framed Power Station structures indicate the close association of ARROL of GLASGOW with Britain's electrical power development. Battersea and others in the London area, Castle Donington in Leicestershire and Braehead at Glasgow comprise a long series now being further extended by the erection of the steel framework of Belvedere Power Station—another of the London Group.

All types of Steel Framed Buildings;
Fixed and Opening Bridges;
Cranes and Mechanical Engineering work;
Dock Gates; Sliding and Floating
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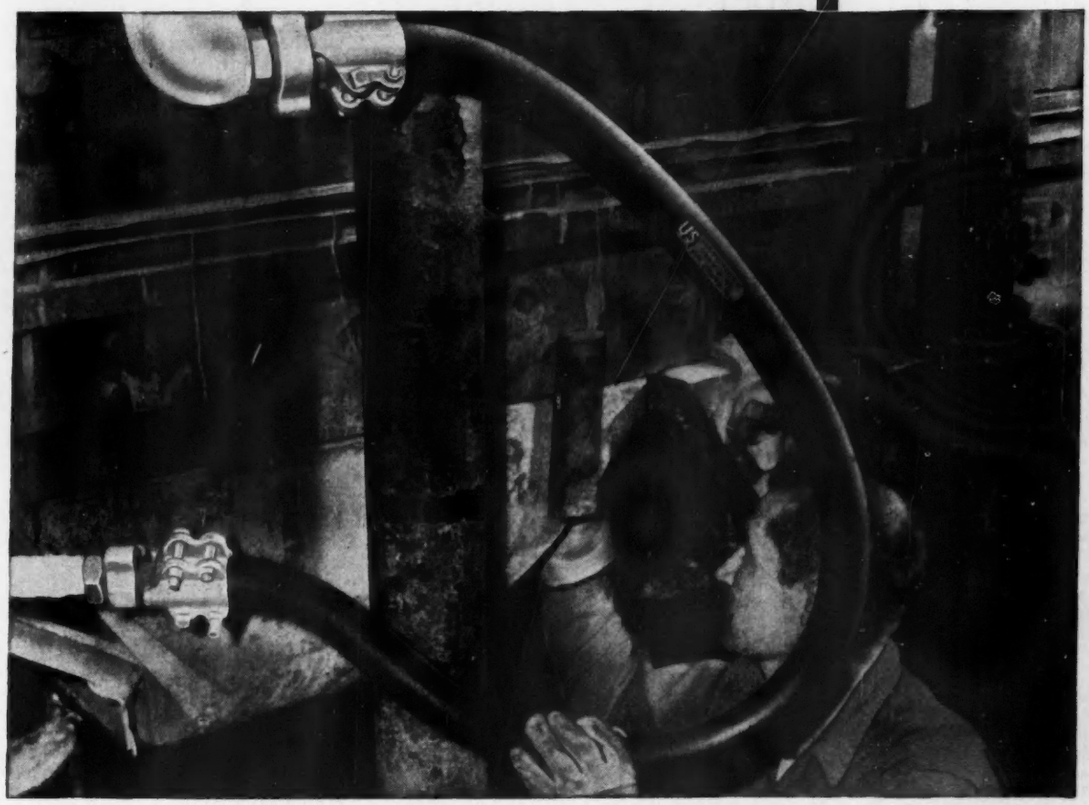
ROBUST IN CONSTRUCTION
WIRE-BRAID REINFORCED
WITHSTANDING
200 LBS. P.S.I.

HIGH
PRESSURE
STEAM HOSE

PLUS POINTS

- *Natural rubber, heavy gauge, seamless tube.*
- *Manufactured in 60 ft. lengths.*
- *High tensile wire-braid reinforcement with special spiral asbestos cord which incorporates a static conducting wire.*
- *Light-weight yet of great strength.*
- *Neoprene cover, compounded to withstand extreme heat and abrasion.*



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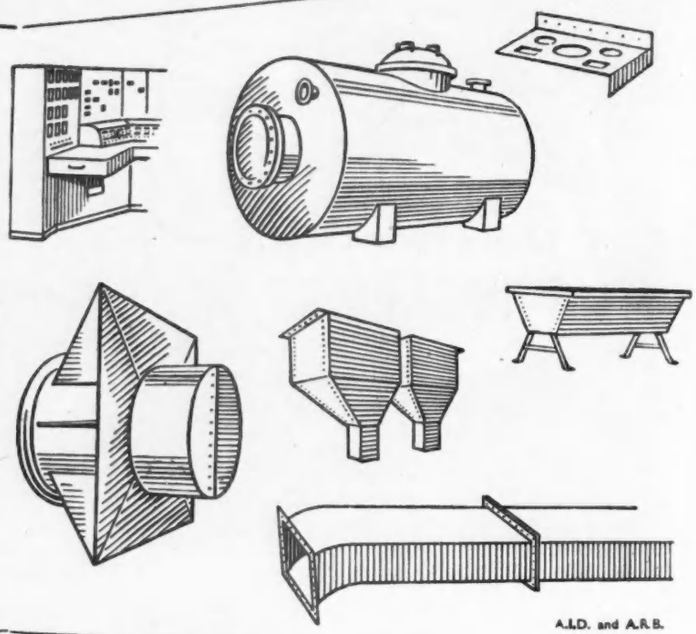

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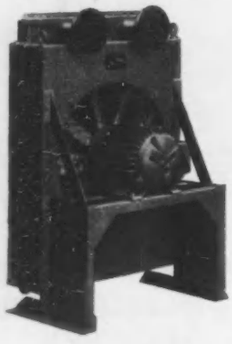

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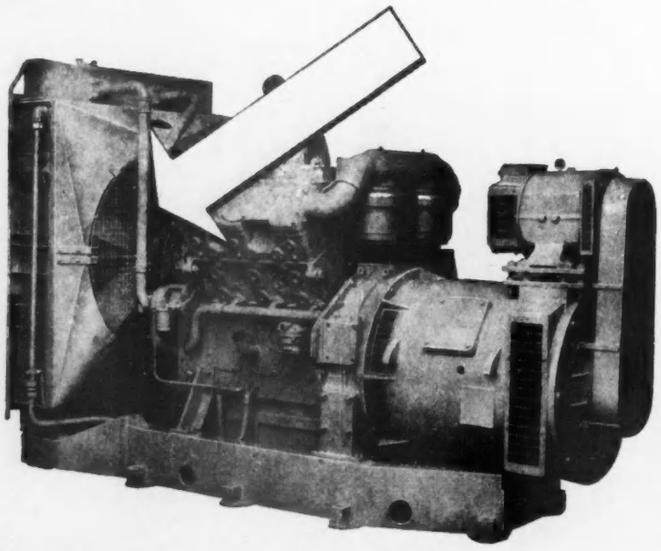

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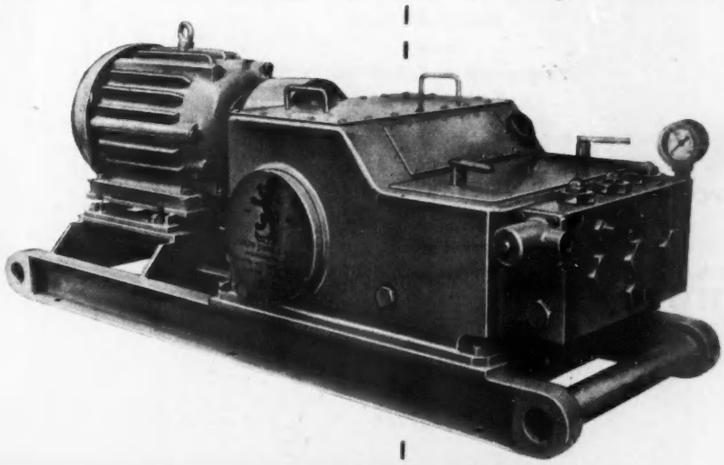

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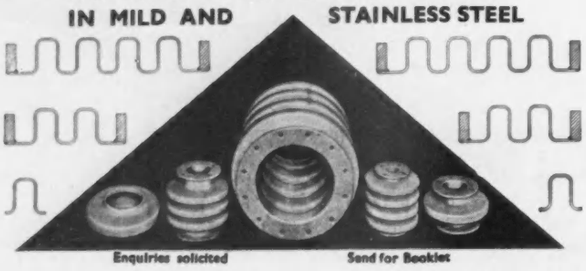

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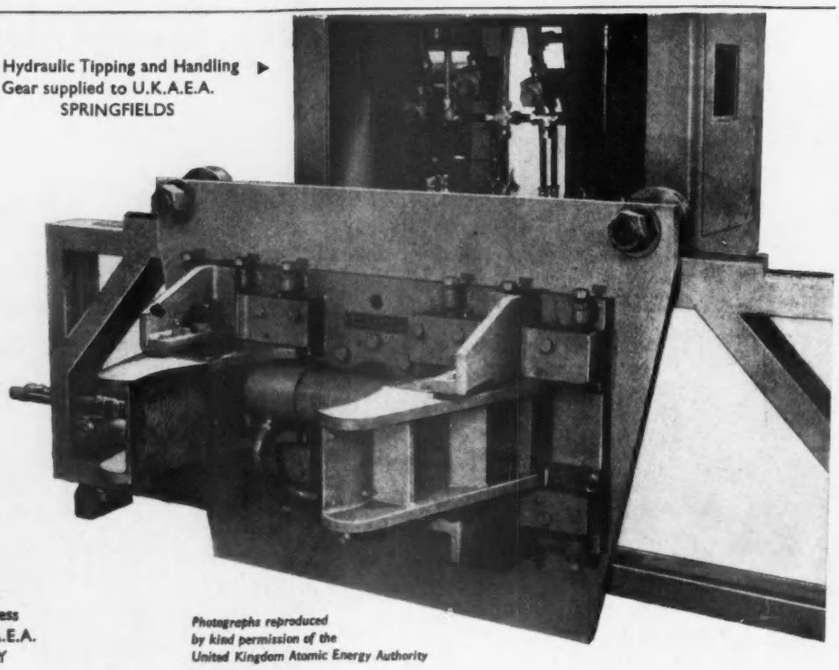

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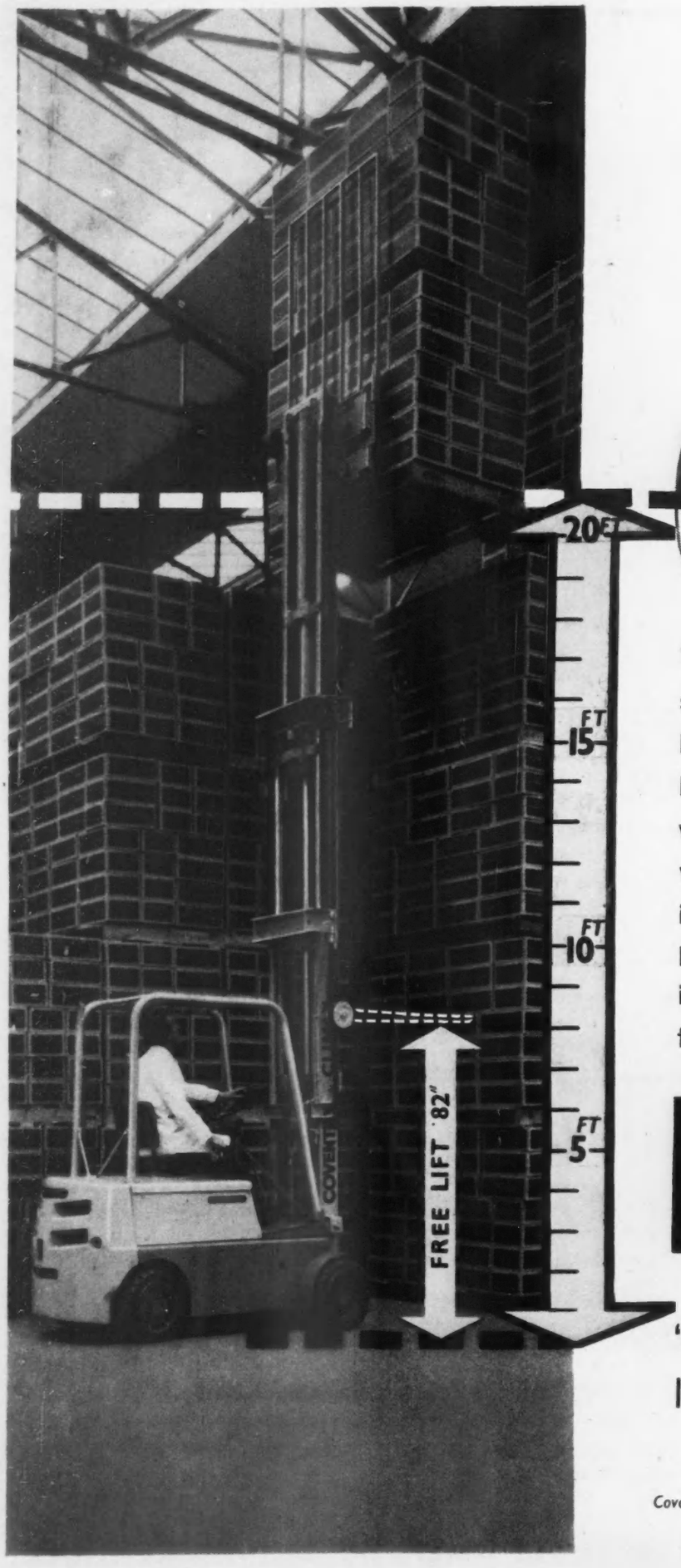

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THE ENGINEER

No. 5431 **FEBRUARY 26, 1960** VOL. 209

DEFENCE WITH SOME DIFFERENCE

The Government's defence programme for the coming year, briefly summarised in these columns a week ago, unlike the Defence White Papers of the past two years, which were little more than progress reports, is of particular interest and importance. The British defence chiefs, like their American colleagues, are clearly having second thoughts about the efficiency of fixed sites for the launching of " deterrent " rocket missiles. The current Defence White Paper states that the development of the " Blue Streak " is to continue but that one may not rely on it exclusively—as the successor to the medium-range bomber with the stand-off powered bomb—if either aircraft or submarines prove effective for long-range delivery of nuclear warheads. This journal has repeatedly emphasised that a deterrent will only be safe, and thus effective, if it is mobile and it is very satisfactory that the Government are now thinking on the same lines. Their intentions, however, are far from clear, and it is to be hoped that Parliamentary debate will throw more light on the position. Britain's contribution to the deterrent would place an impossible burden on her finances if she were to provide both the " Blue Streak," with its costly " hard " underground sites, and large rocket-firing submarines which as at present being constructed in the United States cost over £38,000,000. If the development of the " Blue Streak " is to continue, concurrently with the building of these very large " Polaris " submarines, it seems more likely that only a few of them would be produced for use with the space projects now in hand.

Similarly, the position regarding the air-launched missile requires clarification. It will be many years before a successor to the V-bomber is required. The Americans have a stand-off bomb—the " Hound Dog," with a range of 500 miles—now in production, and are also developing an air-launched ballistic missile. A V-bomber flying at 70,000ft and launching a missile 500 miles or more from the target should be reasonably safe from anti-aircraft measures. In brief, it seems that Britain's share of the deterrent is likely in the future to become wholly, instead of partially, mobile. In other respects the new Minister of Defence has made no changes in the broad defence policy laid down in 1957 by his predecessor. Britain is to continue to make a contribution to the deterrent, both with thermonuclear missiles and with conventionally armed forces, to deal with local emergencies and thus prevent them developing into a major conflict. Indeed, as long as the N.A.T.O. governments—influenced largely by the American view—maintain that a major war would inevitably be fought with thermonuclear weapons, despite the change in the defence outlook since N.A.T.O. was organised over ten years ago, the vast majority of the nation will continue to support the Government in thinking of defence in terms of the various components of the deterrent. In line with this policy, a second nuclear-powered hunter-killer submarine is to be ordered, based on the design of the " Dreadnought," but with British propulsion machinery and a British made reactor, for which a land-based prototype is now under development at Dounreay.

Apart, however, from the announcement of this second nuclear powered submarine and some platitudes about the value of the new ships, aircraft and weapons now in service or shortly to come into service with the Fleet, the 1960 defence programme gives no indication of any expansion of the Royal Navy. Nor does it give us much information about the other two Services which is not obvious or already known. The Army, according to the White Paper, may expect to have vehicles with new multi-fuel engines which promise great economy and flexibility and it is pleasing, though surely not surprising, to read that our new main battle tank will incorporate several new principles of design and promises to be as outstanding in its class as the " Centurion." New weapons for the Army include a 105mm tank gun—already ordered by the United States and Sweden ; the Italian 105mm pack howitzer ; the Australian designed and produced anti-tank guided missile " Malkara " ; and the Canadian " Beaver," as a light liaison support aircraft. The readiness of the V-bombers is to be improved and their dispersal increased. The Mark II " Vulcan," with an improved engine, and Mark II " Victor," with a change of engine, will have better take-off performance and they will be able to fly further and at greater heights. Arrangements have been made with the United States authorities for the erection of a ballistic missile early warning system for this country. Further details have since been given in a separate White Paper. The " Lightning " supersonic fighter is to enter regular squadron service in the next four months and by the end of 1960 a second squadron of the military version of the " Britannia " will be in service with the R.A.F. Transport Command. The " Britannic " will further strengthen the strategic reserve in carrying exceptionally heavy or bulky freight and a military version of the " Argosy " is now on order for the tactical transport force. Pending the development of a more advanced type of helicopter, " Whirlwinds " will be used for the rapid movement of troops within the tactical area. For the first time, the Defence White Paper shows how defence expenditure is divided up. Nearly half the estimate of £1630 million is for Service staff and civilians working with the Forces ; research and development take 14 per cent ; 28 per cent is required for weapons and equipment ; and the balance is for operational works and fuel. Subject to the present satisfactory recruiting rate continuing, the strength of the Forces will be just under 400,000 on April, 1963, when national service ends—about 3000 fewer than now provided for under the current defence plan.

TOO LIMITED A SPACE POLICY?

Many scientists in this country will, no doubt, have been pleased to read in a recent issue about the success of the mission led by Professor Massey to the U.S.A. to decide upon the suitability of suggested British experiments and upon the practicability of including equipment to perform them in small satellites to be launched into orbit by American " Scout " rockets in the not distant future. The choice of experiments, as far as we, as engineers rather than scientists, can judge, seems sound and some of the results may well have value for engineers in certain fields. In fact few people in this country are going to cavil at this latest example of Anglo-American co-operation. But what engineers do cavil at is the apparent assumption by some scientists that the resulting British effort in the field of space research will be sufficient. There seems to be a tendency so far to concentrate activity upon upper atmospheric research rather than upon true space research and to assume that to attempt more would cost more than it would be worth. Earlier this week an adjournment debate in the House of Commons, without adding anything much to existing knowledge, helped to bring the matter into clearer perspective by impressing on the Government such arguments as those we mention here.

To engineers the Governmental undertaking to support " design studies " for a British rocket vehicle based upon the development of " Black Knight " and " Blue Streak " is only satisfactory so far as it goes and it does not go very far ! There is no guarantee that any hardware will result from the work and for that reason it is not likely to prove attractive to young and talented engineers wishing to study rocket problems. We also believe that to certain scientists the limitation of British scientific effort implied by the attempt to economise unduly on the cost of the research is not at all attractive either. It implies that for experience in certain fields of rocketry—notably that of control but also in several others—scientists, like engineers, will have to go to the States ; and, no doubt, since secrecy covers much of the work, become U.S. citizens. Is this country so rich in young and talented engineers and scientists that it can afford to lose many of the best of them to the States ?

The Defence White Paper on which we comment elsewhere in these pages has now introduced a new factor. Clearly the fate of " Blue Streak " as a warlike missile has become dubious. For military thinking is coming round to the view that a more mobile weapon is desirable if a deterrent effect is to be retained. A large part of the cost of the " Blue Streak " deterrent relates to the building of underground launching chambers. If, as now seems quite possible, this programme is given up, there will be far gone in development a rocket weapon designed for use with launching pads which will never come into existence ! In those circumstances we must hope that the design studies will be pushed on really fast so that some real figures for the cost of using " Blue Streak " for space research will become available very soon. But the question does seem to need asking whether it is really necessary to await the results of the design studies before announcing that Britain will use the rocket for space research ? For in the debate Mr. Rippon was able to mention as " feasibility studies " of the " Blue Streak "–" Black Knight " combination a number of attractive projects realisable by the mid-'sixties, far more satisfactory than any which could be carried out by British engineers and scientists in American " Scout " rockets. They ranged from the launching of a satellite of between 1000 lb and 2000 lb weight into an orbit 200 to 300 miles up to the placing of an instrument package weighing about 50 lb into an orbit reaching out 100,000 miles or so from the earth. The present situation is bound to create uncertainty in the minds of rocket engineers and scientists interested in space research as to whether this country may soon decide to drop all work on " Blue Streak " and upon any alternative rocket and confine itself to such upper atmosphere research as can be done with, for example, " Skylark," an altogether smaller device which in its way has proved very successful for that purpose ; and such limited researches as the use of American rockets may permit. But is there really any doubt about the feasibility of using the " Blue Streak "–" Black Knight " combination ? Does not the doubt relate to the cost ? Can the cost possibly be very high ? In those circumstances would it not be advantageous to announce at once that whatever the future of " Blue Streak " as a weapon, work will certainly continue on its development for space research ?

PAVEMENTS IN THE AIR

The speech made by Mr. Ernest Marples, the Minister of Transport, at the opening of Castrol House in Marylebone Road last Monday was widely reported in the daily press. His words are nevertheless worth repeating again here, if only because they reiterate a very fundamental principle in city planning which has been repeatedly emphasised over the past few years in these leader columns. The Minister reminded his audience that there were now 8,500,000 motor vehicles in this country and 15,000,000 were expected by 1975. Then he went on to say : " An orderly flow of cars with the retention of our amenities and the preservation of the character of our cities will be quite a formidable task. There is no simple solution nor any magical formula. It will not be solved by new road engineering alone, nor just by the ingenious application of traffic engineering techniques. It is a problem of planning the environment of the community as a whole. It involves architects, town planners, landscape specialists, engineers—in fact, every ingredient which goes into the creating of a community. We are setting up a long-term study group simply and solely to probe into the future of our cities. We must find a design for living in the last quarter of this century. This magnificent new Castrol Building gives me a chance to mention just two of the many points this study group must consider : first, future buildings must provide for the off-street car parks their own cars will need. Traffic will never flow if cars are dumped into a main street and left there all day. Second, the comprehensive planned reconstruction of our cities must include some multi-level traffic circulation and the segregation of the pedestrian from the motorist. When a ton of steel moving at 30 m.p.h. and 11 stone of flesh and bones moving at 3 m.p.h. share the same surface, accidents must happen —and the flesh and bones won't win. Perhaps in our busy shopping centres the pavements could be lifted to the first floor and cantilevered out. The existing ground level pavement could then be used to widen the existing road. Thus we could have a wider road plus a safer place for pedestrians at the same time."

The really vital point is that the urban motor roads (i.e. the roads giving free and safe traffic flow through the heart of the city) are the basic skeleton around which the city must be formed. Then an almost endless variety of groupings and planning motifs can be created or adapted by perhaps only minor modifications in some cases, clinging around the skeleton, but having in common the segregation of traffic and pedestrians. The same point was made by Mr. Coia, one of the architects who has just returned from the Cement and Concrete

Association's South American tour, "Get the roads right," he asserted, "and the city follows."

In the long term, then, Mr. Marples' concept is clearly on the right lines. His long-term study group is also an idea of great interest, but we feel rather sceptical of its achieving many practical results. By 1975 its work, however inspired, may be safely tucked into a Whitehall pigeon-hole and long forgotten! It is unfortunate that Mr. Marples could not refer more directly to the short term; by contrast with his imaginative conception of the reconstruction of cities the recent report of the Nugent committee on London's roads appears as a monumental example of futility. "Coming to terms with the motor vehicle" is such an urgent and pressing problem, that all those professional specialists—"ingredients" as the Minister called them—need some solid basis for immediate progress. The very least demand, the smallest practical step that could be taken, is that an urban motor road "skeleton" should be delineated for central London. Naturally, it should be based on efficient traffic engineering studies. Even if only a portion could be built, other metropolitan developments could be designed to fit into the pattern of roads to come, and thus make a start in the evolution towards the motor-car city. Planning for this ultimate pattern of segregating motor traffic whilst maintaining and enhancing all other amenities should be inherent in every single development passed in London by the planning authorities. The first step in all this, is a clear statement of the likely pattern of urban motor roads—a skeleton on which to build. Without immediate practical steps of this kind, Mr. Marples will build not pavements but castles in the air.

FIRE PROTECTION

The first National Fire Protection Conference began, in London, yesterday and continues throughout to-day. Over 800 people, including representatives of industry and commerce, public and industrial fire brigade officers and factory inspectors have assembled to discuss a series of papers dealing with many aspects of fire protection and prevention. The importance of the matter is obvious when it is kept in mind that this country's fire losses last year were assessed at as large a sum as £44,000,000. That figure indicates a sharp increase over those of the three preceding years. A big proportion of it represents fire losses in industry and, as was observed at the conference yesterday, it is "a grim reminder of the need to intensify basic fire prevention and precaution arrangements." Some of the increase in fire loss last year can, no doubt, be explained by the unusually dry weather which lasted for many months. But such an explanation must not be permitted to obscure the need for greater effort in the elimination of fire risk. Mr. A. F. O'Shea, chairman of the Industrial Fire Protection Association, who is presiding over the conference, directed attention yesterday to "lack of care on the premises involved (in fire) either in construction, in the system of working, or in day-to-day operation." The fact that, after centuries of industrial, social and educational development, fire still constitutes an undisputed drag on industry as the greatest destructive agent in the world, presents a challenge to all who are concerned with the industry of this, or indeed, of any other country. Happily, the standard of operational safety in industry shows continual improvement. Thus are safety training and accident prevention schemes proving their worth. Similar efforts, aimed solely at fire protection and prevention, are still deserving of the closest study. This week's conference is giving a valuable impetus to that study.

EXPANSIVE GAS

For some not very obvious reason the work of the Central Electricity Generating Board and the Area Electricity Boards in expanding the production and usage of electricity seems to hit the headlines much more effectively than does the work of the Gas Council and its Area Boards in encouraging and developing the production and usage of gas. Yet in its way the progress of the gas industry since it was nationalised has been just as technically interesting as that of the electricity supply industry, as readers of the pamphlet "Gas Looks Ahead," which we reviewed in last week's issue, will be aware. Sales of gas in millions of therms have risen from 2328 in 1949–50 to 2605 in 1958–59, and they are confidently expected to reach 2839 in 1965–66. Predominantly, increases are expected to occur in future in industrial usage, but a modest increase in domestic and a less modest increase in commercial usage are predicted. What is more exciting is that the Council has in its sights a clear conception of the future character of the industry. Instead of a multiplicity of small gasworks—each a smelly eyesore—the Council foresees a future when there will be comparatively very few gasworks of large size situated near coalfields or oil refineries. They will gasify small coals besides coking coals and some oil at high pressures and feed the gas into a pressurised national gas grid connecting together the various gasworks and coke oven plants at steel works and perhaps also plants for producing gas from imported liquid methane. Progress towards this ideal is shown by the figures that, as compared with 1050 works in operation in 1949 when the Area Boards took over, there were only 463 operative in March last year. In addition, the industry, appreciating that good coking coals are in less free supply than they were, is going forward in developing methods of gasification of low-grade coals.

The Engineer—100 Years Ago (FEBRUARY 24, 1860)

"THE BUDGET"

"When everything is dull but politics, and every one we meet is full of the budget and the French treaty, it is impossible for professional reserve to keep its prudent resolutions longer. We must have our say in common with our contemporaries . . . No unprejudiced man can, in his calm moments, we imagine, question the vast commercial benefits that must spring out of the proposed changes. The admission of our two great staple products, coal and iron, into France, must give a great impulse to our mining and metal manufacturing industry. It is impossible to doubt this. The excessively absurd argument which is the main objection to the exportation of coal—that we shall be furnishing France with the means of bringing its steamships against us—merely proves how generally approved this change must be. In fact, no change at all has been made in this respect. The French Government levied a duty on our coals when exported thither, it is true. But the French Government received the duty when it was paid. That is, it took the money out of one pocket and put it into the other. Now it saves itself the trouble of doing either . . . .

"The concurrent home changes proposed are in the main wise, broad, and liberal. It is healthy to set commerce free from vexatious and peddling restrictions, that are little productive to the revenue and yet obstructive to trade. Free paper is too much allied to free knowledge not to be a boon. If we are to have the income-tax let us have its basis corrected, its assessment and collection improved, and then few will grumble at its permanency."

Obituary

SIR DAVID R. PYE, C.B.

We record with regret the death of Sir David Randall Pye, which occurred last Saturday, February 20, at his home at Shackleford, Godalming, after a long illness. Sir David, who was seventy-three, was a past-president of the Institution of Mechanical Engineers, and was one of the few engineers, apart from professors, to hold fellowships at the universities of Oxford and Cambridge.

Sir David began his education at Tonbridge School and went on from there to Trinity College, Cambridge. He was one of three men to secure a First Class in the Mechanical Sciences Tripos in 1908. Immediately thereafter, he spent some time in the works of Mather and Platt, Ltd., to gain practical engineering experience. In 1909, Sir David was invited to become a lecturer at the new engineering laboratories at Oxford University and was elected a Fellow of New College. In the succeeding two or three years, he did a great deal of lecturing and, in addition, assisted Professor Frewen Jenkin in an extensive research programme, one of the results of which was the establishment, for the first time, of accurate figures for the physical properties of refrigerants at low temperatures.

Soon after the start of the first world war, Sir David was commissioned in the Royal Flying Corps as an experimental officer at the Armament Experimental Station at Ordordness. Subsequently, with the formation of the Royal Air Force, he was transferred to the aeroplane testing station at Martlesham Heath where, it is said, he learned to fly as a pilot. Following his demobilisation in 1919, Sir David resumed his work at Oxford University, but during the summer of that year, he was invited to return to Cambridge as a Fellow and Lecturer at Trinity College. Apart from his engineering lecturing at Cambridge, Sir David participated over the next six years in a research programme on the combustion of volatile fuels. Much of the work was carried out at Sir Harry Ricardo's works at Shoreham.

Sir David R. Pye, C.B.

In 1925, a directorate of scientific research was established at the Air Ministry under Dr. H. E. Wimperis. Sir David was invited to join Dr. Wimperis as deputy-director. When Dr. Wimperis retired in 1937, Sir David succeeded him as director of research at the Air Ministry and in that office was mainly responsible for the development of methods and equipment to enable the Royal Air Force to accomplish so successfully its role in the second world war. Sir David continued his work at the Air Ministry until 1943 when it was decided that the research programme could be limited to projects which could be expected to result in effective weapons of war within two years. On that account, Sir David was permitted by the Air Council to relinquish his appointment as director of scientific research, when he was invited to become Provost of University College, London. His Provostship was no sinecure ! University College had suffered severely in the air attacks on London in 1940–41 and, in consequence, all the staff and students had been evacuated to seven different centres in various parts of the country. Before the war had finished, Sir David was occupied with plans for rebuilding the college, acquiring new sites for its future development and for making possible the re-integration of the scattered faculties of the college into a single community. By the time Sir David retired from the office of Provost in 1951, most of that task was successfully accomplished. In the New Year Honours of 1952, his work for University College was fittingly recognised by the conferment of a knighthood ; he had received the honour of C.B. in 1937.

Sir David had been a member of the Institution of Mechanical Engineers since 1934 and was first elected to its council in 1943. Shortly after his retirement from the Provostship of University College, he was elected president of the " Mechanicals." His presidential year was an important one, as it was a year in which close study was being given to the future of technical education. In that study, Sir David's experience and scholarship were a great asset. Inevitably, his presidential address, delivered in October, 1952, was devoted to the subject of the higher education of engineers. In that address, Sir David emphasised that engineering was an art as well as a science ; he did not hesitate to criticise engineering education for its lack of attempt to give some experience of the reality of design procedure. Sir David took the view that the art of engineering included a great deal that was outside " formulated theory." The rule-of-thumb, he said, played, and would always play, an important part, and rules-of-thumb, Sir David added, were accumulated by experience.

Opinion of this kind, cogently expressed by Sir David, was unquestionably valuable in any consideration of future trends in technical education. He did not shrink from saying what he thought was needed, as the following quotation from his " Mechanicals " address indicates : " The growing tendency to-day is to recruit from among those who have taken university degrees ; we may perhaps assume as a working hypothesis, but with many notable exceptions, that as a class the ablest recruits to the engineering profession find their way to the universities. We should therefore look to the universities to feed back into industry first-class minds with a well-balanced scientific and technical background ; many of them minds that are ready to be stimulated to creative activity by contact with the practical needs of industry. Are we choosing the right way to set about the task of providing the needed background while at the same time retaining sufficient flexibility in the courses to allow the spark of originality, when it exists, to grow ? . . . . Even if one cannot hope to introduce the atmosphere of a design office it would be something achieved if the university student could be made more aware of the importance of design in the progress of engineering."

As well as being a past-president of the Institution of Mechanical Engineers, Sir David was a Fellow of the Royal Society and a Fellow of the Royal Aeronautical Society. To the latter Society, he delivered the Wilbur Wright memorial lecture in 1936. He was also an Honorary Fellow of University College, London, and an Honorary Fellow of the Institute of the Aeronautical Sciences (U.S.A.). Furthermore, Sir David was the author of a number of technical, and non-technical, books and of many scientific papers.

We suspect that a meeting with Sir David seemed in prospect a somewhat daunting experience to young men. For he looked so much what he was, a very clever man with a deep insight into technical problems and no truck whatever with any kind of folly ! But closer contact revealed a mind, firm enough but also kindly, an unsuspected depth of modesty, and an underlying humour. Sir David was among the leaders of those who got theoretically well educated young men appreciated in this country in what was before regarded as a very practical art. It thus seems a little paradoxical to learn how insistent he was upon the need for training in the art as well as the science of engineering design and to discover his respect for " rules of thumb." But in fact there was no inconsistency. For the pioneers of higher technological education would very probably not approve to-day's tendency to rate research as a higher form of engineering activity than design. Sir David had experience in both fields and had no illusions. He questioned, as many have continued to question since, whether modern university courses in engineering are producing men with the qualities needed by designers.

Specification and Testing of Filters and Water Separators*

By L. R. BEYNON† AND R. W. CRANSTON†

The advent of turbine and jet aircraft has introduced the need for aviation fuels which are virtually free from all contamination by solid particles and water. The need to provide equipment to ensure that fuel is maintained in a clinically clean state led to the work described in this article. In particular a parameter called the transmission curve has been derived for filters, which is the most fundamental and useful expression of the filtration efficiency of a filter, to replace the obsolete concept of cut-off size. Suitable test methods are also described which enable the transmission curve and the other important parameters of filters and water separators to be derived.

IF the fuel supplied to an aircraft contains solid matter, many harmful effects can result. For example, particulate matter causes abrasive wear in fuel pumps. It may also clog orifices and jam valves in fuel control systems which have small clearances. The presence of free water in aviation fuel also has to be avoided, both from the corrosion aspect and because, under certain flying conditions, free water becomes ice which may cause blockage of fuel filters and flow meters. Aviation fuel is therefore protected against dirt and water at all stages from the refinery to the airfield, and as a final safety measure it is passed through a fine particle filter and a water separator prior to being used for fuelling aircraft.

This paper is divided into three parts. Part I contains a brief analysis of the action of fine particle filters and indicates their fundamental parameters. Part II describes how this analysis is applied to laboratory and full-scale filter tests. Part III describes the techniques which are suitable for assessing the efficiency of a water separator/filter unit.

PART I: PRINCIPLES OF FILTER TESTING

Any fuel filter has two very important characteristics, namely :

(*a*) Its filtration efficiency—that is the reliability with which it removes particles of various sizes from the fuel, and

(*b*) Its resistance to flow, which determines the throughput of a filter for a given pressure differential across the filter.

There is no difficulty in finding a material which will give any required degree of filtration. High filtration efficiency is, however, incompatible with high flow efficiency for a given area of filter medium. The practical problem is therefore to find the filter material having the highest flow efficiency per unit area that gives a specified degree of filtration. Also the filter material must not become blocked unduly quickly and it must be suitable from a mechanical standpoint, not corroding or tending to disintegrate under working conditions.

For transmission type filters, with which this paper is concerned, liquid flows through the filter medium and the filtering action depends on the pore structure of the medium. A complete filter may consist of one or more of a variety of materials, including wire or fabric cloths, paper, porous plastic, felt and sintered metal.

There is an important distinction between media which provide filtration in depth, that is where any particle has to pass through a series of pores in traversing a filter, and those which do not, a particle having to pass through only one pore. Simple wire and fabric weaves belong to the second class and have the advantage of being easily cleaned after use. The remaining materials listed above normally provide filtration in depth to a greater or lesser degree and so give the following advantages over those possessing only one layer of pores :

(*a*) Long needle-shaped particles cannot pass through.

(*b*) The effective pore size of the material is reduced because a particle has to pass through several pores in series to pass through a filter (see Fig. 1) and the chances of its

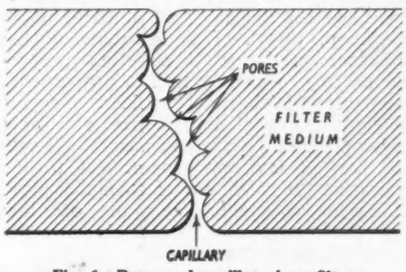

Fig. 1—Pores and capillary in a filter

encountering a pore smaller than itself are thereby increased. Of course, once trapped, this particle itself creates a barrier to even smaller particles which may follow it.

Considering the flat transmission type filter represented in Fig. 1, the term " capillary " is used to describe any channel from one side of the medium to the other. The term " pore " is used to describe any individual constriction in a capillary. The " cut-off " size of any pore or capillary is defined as the diameter of the largest sphere which will pass through it.

ABSOLUTE AND EFFECTIVE CUT-OFF SIZES

It can be shown that in any large area of filter medium there will be a small but finite number of capillaries having cut-off sizes right up to the largest pore sizes. For instance, in Fig. 2, point C represents the size of the largest pores (the termination of the pore size distribution curve), and it also represents the size of the largest capillaries (the termination of the capillary size distribution curve). Suppose that the largest capillary contained in a batch of material to be made up into filter elements is represented by point C, whilst the largest capillaries in the individual filters produced from this batch are signified by points C_1, C_2, &c. Suppose, too, that C' is the point beyond which only a very small proportion (0·1 per cent, say) of the capillaries in the original batch occur, and that C_1', C_2', &c., are corresponding points for the individual filters. It can be shown that, provided the pore size distribution curve descends gradually to point C and not steeply, C_1', C_2', &c., are bound to be much more nearly equal than C_1, C_2, &c. In fact, they are a factor of the order of $\sqrt{N}$ nearer together, where N is the average number of pores per filter between C and C'.

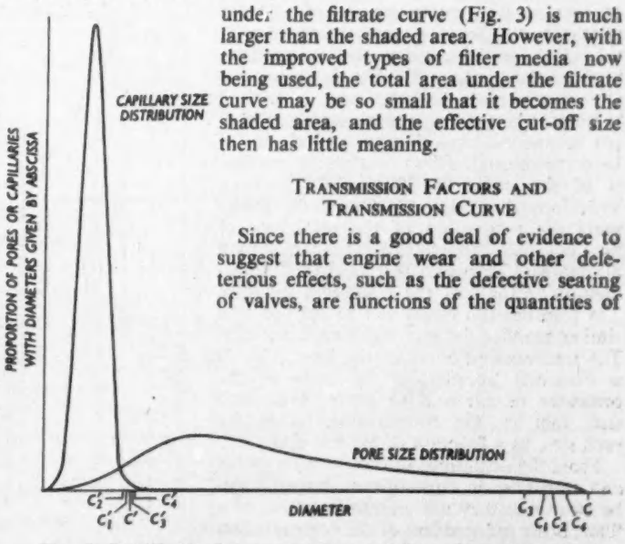
PROPORTION OF PORES OR CAPILLARIES WITH DIAMETERS GIVEN BY ABSCISSA
CAPILLARY SIZE DISTRIBUTION
PORE SIZE DISTRIBUTION
DIAMETER

Fig. 2—Relationship between capillary and pore size distribution

If it is desired to compare the relative efficiencies of two different types of filter, or alternatively to keep control of the quality of different batches of a given type of filter, then clearly a test based on the measurement of some such " effective cut-off size " as C' is more desirable than one based on the measurement of absolute cut-off size. If, however, it is intended to test every filter to be used—a most unlikely occurrence—then measurements can theoretically be based either on the effective cut-off size C', or on the absolute cut-off size C, depending on whether the relative numbers of particles smaller than the absolute maximum admitted to the filtrate, are considered significant or not.

In terms of quantities of particulate matter in the fuel, diameter D (Fig. 3) is the effective cut-off size of the filter when the shaded area under the filtrate curve is a specified small proportion, P, of the total area under the feed curve.

The effective cut-off size is a satisfactory measure of the efficiency of a filter in removing large particles only if the total area

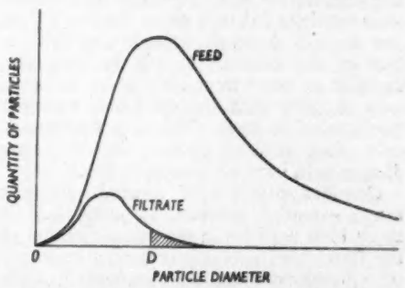

Fig. 3—The concept of effective cut-off size

under the filtrate curve (Fig. 3) is much larger than the shaded area. However, with the improved types of filter media now being used, the total area under the filtrate curve may be so small that it becomes the shaded area, and the effective cut-off size then has little meaning.

TRANSMISSION FACTORS AND TRANSMISSION CURVE

Since there is a good deal of evidence to suggest that engine wear and other deleterious effects, such as the defective seating of valves, are functions of the quantities of

* This unpublished paper was presented at the International Air Transport Association Fuel Study Group Meeting in New York, December, 1959.

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particles of all sizes present and are not just due to the largest particles, a full filter specification should include the performance for particles of all sizes.

The efficiency of a filter below its absolute or effective cut-off sizes is illustrated in Fig. 4, which shows in curve *A* the particle

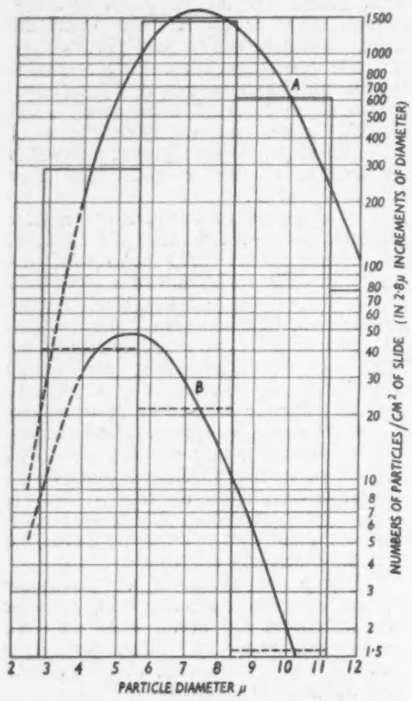


Fig. 4—Example of particle size distributions of a feed and a filtrate for a paper filter

size distribution of a suspension of spherical glass particles fed to a paper filter in a test, and curve *B* shows the particle size distribution of the filtrate. It will be seen that curve *B* is lower than curve *A* at all sizes, thus showing that the filter has removed particles of all sizes. The curves approach each other at small particle sizes and they diverge with increasing particle size.

Consider particles of a small diameter range around 8 microns, for example. Of every 1500 particles in the suspension fed to the filter, fifteen encounter capillaries larger than 8 microns and are transmitted, while the remainder encounter capillaries smaller than 8 microns and are retained by the filter. In practice the rate of motion of particles relative to the liquid is small compared with the velocity of the liquid, so that the particles tend to travel along the liquid streamlines (10 micron glass particles have a settling velocity in kerosene of approximately 2·5mm per minute, whereas the average velocity of kerosene through a filter medium in practice is of the order of 250mm per minute). Therefore the ratio 15/1500=0·01 represents the proportion of the total rate of flow of *liquid*, through capillaries larger than 8 microns. This ratio is termed the "transmission factor" of the filter at 8 microns. The transmission factor can be derived in a similar manner for any other capillary size. The transmission curve of the filter (Fig. 5) is obtained by plotting the ratio of the ordinates of curve *B* to curve *A* at each size, that is, the transmission factor for each size, as a function of particle size.

From the definitions of transmission factor and transmission curve given above, it will be clear that they are unique functions of a filter, being independent of the concentration and size distribution of the contaminant in the feed and therefore also independent of the method of measuring the size distribution (i.e. whether on a number, cross-sectional area, or weight basis). None of these properties of independence apply to the effective cut-off size of a filter and all the above factors have to be closely specified in formulating a test based on effective cut-off size. The transmission curve is the most fundamental and useful expression of the filtration efficiency of a filter. From a knowledge of this curve, the quantity of particles of any size in the filtrate can be calculated theoretically for a feed of any known particle size distribution and concentration.

A further advantage is that the transmission factor at any particular size is a simple exponential function of the thickness of the filter, so that if the transmission factor is known for a single layer of filter medium, that for two or more layers in series can easily be calculated. The exponential nature of the function can readily be seen by considering a filter comprising several identical layers of material in series. Let us suppose that each layer has a transmission factor (5 microns) of, say, 0·1. Then on the average for every thousand 5 micron particles fed to the filter, a hundred are transmitted by the first layer; thus a hundred particles are fed to the second layer and ten particles are transmitted by it and so on. Thus n layers of the material have a transmission factor of $(0{\cdot}1)^n$. The logarithm of the transmission factor is therefore proportional to n, which in turn is proportional to the total thickness of the filter. Now for a given quality of filter medium and for a fixed pressure differential across it, the rate of flow is inversely proportional to the thickness for conditions of streamline flow. Thus for varying thickness, the logarithm of the transmission factor is inversely proportional to flow rate.

The strong dependence of transmission factor on thickness of filter medium is worthy of particular note and is illustrated by the simple hypothetical example given in Table I. Thus a fine particle filter having a transmission factor of 0·01 at, say, 10 microns would be classed as poor; however, two in series would have a combined transmission factor of 10^{-4} and three or four in series would provide extremely efficient filtration at this size. Even a material

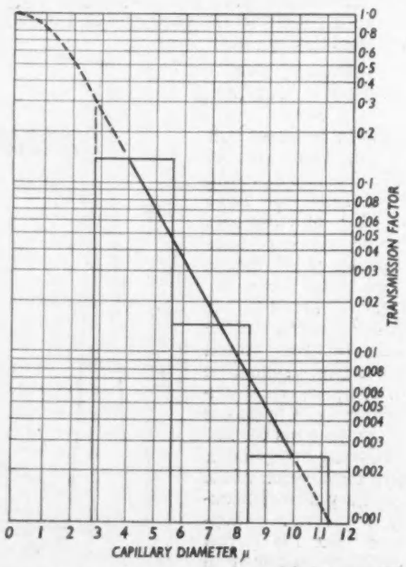


Fig. 5—Transmission curve for a paper filter

TABLE I—*Theoretical Dependence of Transmission Factor at any Given Size on Number of Layers of Filter Material*

Assumed transmission factor for 1 layer	10^{-1}	10^{-2}
Calculated transmission factor for 2 layers	10^{-2}	10^{-4}
Calculated transmission factor for 3 layers	10^{-3}	10^{-6}
Calculated transmission factor for 4 layers	10^{-4}	10^{-8}

having a transmission factor as high as 0·1 becomes reasonably efficient when three or four layers are used in series. The main disadvantage of using filter media in series is, of course, that the flow rate decreases proportionately with number of layers. The logarithmic relationship between transmission factor and flow rate, quoted in the last paragraph, enables the thickness of a filter medium of any known quality to be chosen to give the optimum compromise between high filtration efficiency and high flow efficiency.

For many purposes it is more convenient to consider the logarithm of the transmission factor rather than the transmission factor itself. Since the latter is inevitably smaller than unity, its logarithm is negative. For practical purposes it is convenient to drop the negative sign, which is equivalent to quoting the logarithm of the reciprocal of the transmission factor. It is convenient to plot transmission curves on logarithmic paper since the transmission factors of most filter media decrease rapidly with increasing capillary diameter.

It is convenient to have a single figure for describing the efficiency of a filter, and this can be achieved by quoting its transmission factor at an appropriate size, say, 5 microns. Of hardly less importance, however, is the efficiency of removal of particles smaller than this size. For example, it is possible that two different filter media both have a transmission factor of, say, 10^{-4} at 5 microns, although they have values of 0·1 and 0·01 respectively at 2 microns. Clearly these filters have quite different transmission properties, and, other things being equal, the one having the value of 0·01 at 2 microns would be preferred. An additional test of filtration efficiency is therefore adopted, namely the measurement of the transmission curve. It is recommended that the maximum acceptable ordinate of this curve should be specified at certain sizes, for example, 2·5, 5·0, 10·0 microns, &c.

Flow Factor

The determination of a transmission curve defines exactly the performance of a filter at all sizes. However, the achievement of a filter having a suitable transmission curve is not the complete answer. The filter must also have suitable flow rate/pressure differential characteristics. Under the usual working conditions, the flow through a fine particle filter is streamline. The rate of flow through a cylindrical capillary is then given by Poiseuille's Law which may be stated thus:

$$q=\frac{\pi d^4 P}{128\eta L} \quad \ldots\ldots\ldots \quad (1)$$

where q is the rate of flow in ml/second, P is the pressure drop in dynes per square centimetre along length L cm of capillary, η is the viscosity in poises and d is the diameter in centimetres.

An array of pores in series, such as is shown in Fig. 1, may be considered as a capillary of variable cross sectional diameter, so that the flow equation may conveniently be written in differential form, as follows:

$$q=\frac{\pi d_L^4}{128\eta}\cdot\frac{dP}{dL} \quad \ldots\ldots\ldots \quad (2)$$

Integrated over the length L' of capillary, this becomes

$$q=\frac{\pi PD'^4}{128\eta L'} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

where D' is the effective flow diameter of the capillary, and is defined by the equation

$$\frac{L'}{D'^4}=\int_0^{L'}\frac{dL}{D_L^4} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Now D' is approximately proportional to D (the size of the largest sphere which can pass through the capillary) for a given filter medium and L' is proportional to L, the filter thickness. Let the constants of proportionality, characteristic of the filter medium, be α and β respectively, so that α includes a shape factor for the pores. The flow through the capillary can therefore be written in terms of the capillary size and filter thickness as

$$q=\frac{\pi\alpha^4}{128\beta}\cdot\frac{PD^4}{\eta L} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

which is the basic equation of flow for a single capillary in a plane transmission filter.

The total rate of flow of liquid through a filter depends on the number and size distribution of its capillaries. Let F be the distribution function defining the number of capillaries of each size per unit area. Then, from equation (5) the rate of flow for unit area of a plane transmission filter is given by :

$$Q=\frac{KP}{\eta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

where

$$K=\frac{\pi\alpha^4}{128\beta L}\int_0^{\infty}D^4F(D)dD \quad . \quad . \quad . \quad (7)$$

K is, therefore, a constant characteristic of the filter and is called the flow factor. It is the basic flow parameter of the filter and is evaluated experimentally from equation (6).

Part II : Filter Tests

The first consideration when conducting filter tests is the choice of contaminant. Although no two samples of fuel in the field are ever contaminated in precisely the same way, it is of interest to consider a typical example. Fig. 6 shows the contaminant found on an aviation fuel filter in service, whilst Table II shows its particle size distribution. Such a contaminant consists of

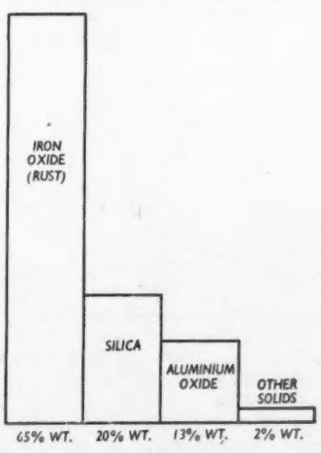


Fig. 6—Composition of typical contamination found on a filter

Table II—*Particle Size Distribution of Typical Contamination Found on a Bulk Fuelling Filter in Service*

Particle size range	Per cent (by weight) of contamination
Up to 5 microns	20
5 to 10 microns	20
10 to 20 microns	10
20 to 200 microns	50

irregular particles, so that it might be concluded that an irregular shaped contaminant should be used in filter tests. There is, however, much to be said in favour of using spherical contaminant particles for filtration assessments. For example :

(i) Most methods of analysis yield uncertain results for irregular particles ;

(ii) The test particles should be easily distinguishable from extraneous matter in any microscopic analysis ;

(iii) In order to predict the behaviour of

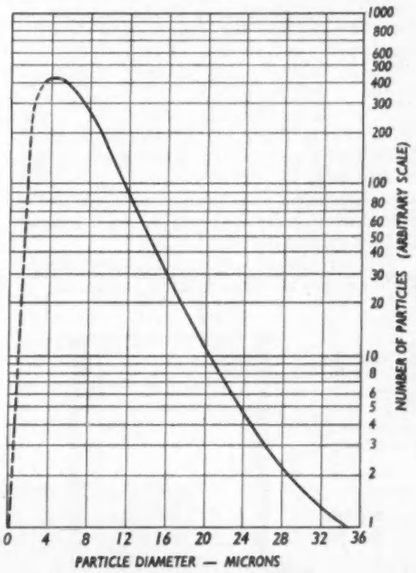


Fig. 7—Particle size distribution of zinc dust used as artificial contamination

a filter with a naturally contaminated fuel containing particles of different shape from those used in the test, it is necessary to invoke the use of two particle shape factors ; one for the test contaminant and the other for the contaminant under consideration. The behaviour of a filter cannot in general be predicted by using angular particles of arbitrary shape for the test and assuming that they will give the same results as the particles occurring in the natural suspension. Shape factors for all but spherical particles are the least certain of the various factors incurred in assessing a filter. It is obviously desirable to reduce this uncertainty, and this can be done by using spherical particles for the test contaminant, resulting in a shape factor of unity.

The most accurate value of transmission factor is obtained using spherical particles having a narrow size range around the size in which one is interested. For laboratory tests narrow cuts of spherical glass are ideal as contaminant and the British Petroleum Company has manufactured small amounts of this material. For the relatively large quantity of contaminant required for testing a bulk fuelling filter, however, the preparation of such narrow cuts is impractical in the laboratory, and even a wide particle size distribution of spherical glass with lower size limit below 5 microns is commercially unavailable at the moment. For large-scale tests, therefore, a commercial zinc dust is used, consisting of spherical particles having a size distribution between 2 and 30 microns, peaking on a weight basis at 8 microns and on a number basis at about 4 microns (Fig. 7). Transmission factors are then measured in suitable increments of diameter, using this wide range contaminant, and the transmission curve is obtained by plotting these values against particle diameter as a histogram, and drawing a smooth curve through the histogram (Figs. 4 and 5). The transmission factor at any size can then be read from this curve.

The use of zinc as a contaminant has other advantages when analysing fuel samples. These will be discussed later.

Laboratory Measurements

(*a*) *Flow Factors.*—Fig. 8 shows an apparatus which is convenient for determining the flow properties of a filter medium. It consists of a 2in internal diameter filter chamber, a reservoir, variable throughput pump, auxiliary filter and a mercury manometer. The apparatus is constructed mainly in glass so that the filter can be viewed during test and so that any entrapped air in the system, which might otherwise give spurious pressure readings, can be located immediately and eliminated.

When it is desired to test a flat transmission type of filter medium, several 2¾in diameter discs are cut from the medium and are tested in turn by sealing in the housing shown in Fig. 8. Filter elements of cylindrical and other shapes can equally well be accommodated in the apparatus by replacing the normal demountable filter housing with one constructed to fit the particular element.

The mode of operation of the apparatus is straightforward. The kerosene or other test fuel is contained in the reservoir and is pumped to the filter under test at any selected flow rate up to a maximum of 2·5 l per minute. For measurements of flow rates, nominally clean fuel is used and prefiltered through the auxiliary fine particle filter shown. This is a necessary precaution to prevent gradual blockage of the test filter and consequently an unstable pressure reading. The pressure difference across the filter is indicated

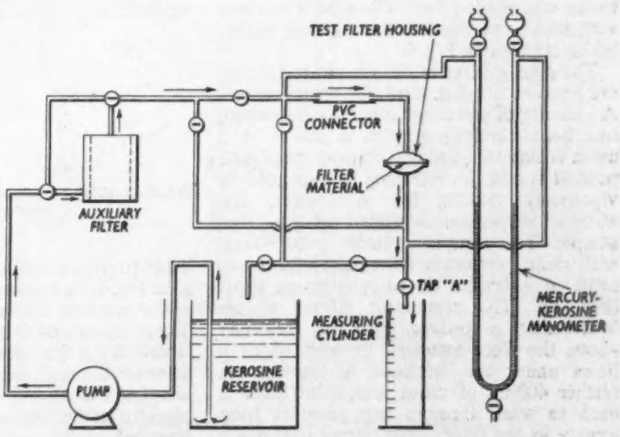


Fig. 8—Laboratory apparatus for measuring flow factors

by a mercury manometer, the entire apparatus as far as the mercury surfaces being filled with kerosene, and all bubbles of air are eliminated by suitable control of the taps shown. On test, the direction of flow of the fuel is indicated by the arrows in Fig. 8, and the rate of fuel flow is measured by timing the flow from tap *A* into a measuring cylinder.

Rates of flow are measured at several different pressures and a graph of flow rate versus pressure drop is drawn. This is checked for linearity to confirm that flow is streamline, and the flow factor, which is given by :

$$K=\frac{\eta Q}{P}, \text{ (see equation (6))}$$

is calculated from the best straight line through the origin and the experimental points. The viscosity of the kerosene is usually obtained by interpolation from measurements of its viscosity at two standard temperatures.

(*b*) *Transmission Factors.*—It is normal practice to assess the filtration efficiency of filter media in the clean state, that is when the efficiency is a minimum. The results given in Table III indicate that the transmission

TABLE III—*The Effect of Feed Concentration on Transmission Factor for a Paper Material (Using 5 micron Glass Spheres as Contaminant)*

Weight of contaminant in feed (grammes)	Theoretical thickness of layer* (microns)	Transmission factor
0·035	4·5	0·0005
0·070	9	0·0006
0·140	18	0·00014
0·210	27	0·00006

* Assuming that all the particles in the feed are deposited on the top surface of the paper and that the particles are packed as closely as possible.

factor at 5 microns decreases rapidly when the weight of contaminant deposited on the filter exceeds 70 milligrammes for a 3in diameter disc. The recommended test procedure quoted below is based on this finding. If all the spheres were packed tightly on the front surface of the filter, this weight of deposit would represent an average thickness of 9 microns, that is almost two particle diameters. In actual fact, the particles will be deposited throughout the bulk of the filter and not just on the surface, so that the experimental findings do not contradict the theoretical expectation that the transmission factor will decrease as the amount of contaminant deposited on the surface approaches an average thickness of 1 particle diameter.

The filter material under test is cemented to the ground glass end of a glass tube measuring 3in i.d. by 4in long, and is trimmed to the size of the tube. The tube is retained with its axis vertical above a settling beaker which is shown in Fig. 9.

The glass spheres in the size cut to be used are dried at 120 deg. Cent. for several hours. A quantity of petroleum ether (440 ml) which has been carefully filtered, is placed in a clean Winchester, and 0·0385 gramme of glass powder is added. The glass is suspended by vigorously shaking the Winchester, and 40 ml of suspension is drawn off as a feed sample. This sample is made up to 800 ml with clean petroleum ether, and allowed to settle in a beaker on to microscope slides (Fig. 9). The remaining 400 ml in the Winchester is poured into the reservoir above the filter material, through which it flows under the influence of gravity. A further 400 ml of clean petroleum ether is used to wash through any particles lying loosely in the filter. The filtrate (800 ml) is also allowed to settle in a beaker on to microscope slides. When sufficient time has elapsed for all the spheres to settle out, the petroleum ether is slowly drained away, the slides are allowed to dry and are then protected by cover slips.

To obtain a filter assessment from these slides, a projection microscope, containing a calibrated graticule in its eyepiece, is used. The smallest divisions of the graticule should correspond to 2–3μ increments on the slide and to 3–4mm when projected on to the screen. The slide under inspection is moved across the field of view in a direction perpendicular to the graticule. The particles are counted as they cross the graticule and the area of slide, traversed in obtaining a count of 400 particles, is determined.

The transmission factor is the ratio of this area for the feed to the corresponding area for the filtrate, divided by ten (the ratio of the volumes of original suspensions taken).

(*c*) *Transmission Curves.*—The procedure used for determining transmission curves is the same as that for transmission factors, except that a contaminant covering a suitable range of particle sizes is used. For convenience, the glass spheres that are obtained as a by-product in the preparation of the narrow cuts have frequently been used. They have a particle size distribution mainly in the range 2·5 to 12 microns. Zinc dust and other spherical contaminants are available commercially and may be used instead of glass spheres if desired.

The particles are counted as before, but in addition they are sized in small increments of

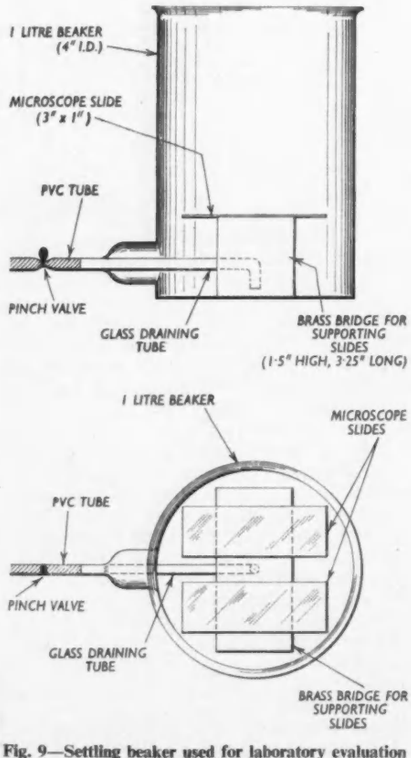


Fig. 9—Settling beaker used for laboratory evaluation of transmission factors

diameter (for example, in 2·8 micron steps, as in Fig. 4) by estimating how many divisions of the graticule are covered by each particle. The corrected ratio of filtrate to feed counts is calculated for each step in an analogous manner to that described above, and a histogram is drawn, as in Fig. 5. The best smooth curve through this histogram is accepted as the transmission curve of the filter.

TESTS ON COMPLETE FILTER UNITS

(*a*) *Test Rigs.*—A photograph of the test rig used at the B.P. Research Centre for assessing filter units is shown in Fig. 10, and a pipeline diagram is given in Fig. 11.

Great care has been taken to eliminate unwanted foreign matter (as distinct from artificial contaminant) from the system, and to this end all the pipelines are made from glass, stainless or tinned steel. In addition to being corrosion free, the glass pipe facilitates observation of the fuel as it passes to and from the test unit, and gives immediate indication of air locks and settling out of contaminant in the system. The fuel storage tanks, each with a capacity of 1000 gallons, are made from stainless steel. The fuel is pumped by a centrifugal pump of the type used in aircraft fuelling operations. It is driven by an electric motor, and the system is capable of variable rates of flow up to 260 Imperial gallons per minute, which was the maximum fuelling rate envisaged when the rig was built. The rate of fuel flow and the total quantity of fuel passed on test are indicated on a combined flow and integrating meter, and facilities are provided for measuring the line pressure and differential pressure across the unit under test. To safeguard against fracture of the glass pipes by vibration or by rig movement, due to initial surge pressure, bellows units are introduced into the pipeline at several points. These bellows, which are restricted so that they cannot expand longitudinally, can be seen in the photograph of the rig (Fig. 10) but for simplicity are not shown in the pipeline diagram (Fig. 11). An auxiliary filter is included in the system for precleaning the fuel ; tests are carried out to a standard technique, using 1000 Imperial gallons of fuel.

So that the rig already described can be released for more fundamental studies, and also to facilitate the testing of larger units, the British Petroleum Company have built another rig to undertake all routine testing. A pipeline diagram of this rig is shown in Fig. 12. It has a flow capacity of 500 Imperial gallons per minute which can be uprated in the future if required. The rig has three 5000 Imperial gallon storage tanks, a water supply tank and a fuel dump tank for filter back-flushing tests. Both an auxiliary filter and a water separator are included in the line for precleaning the test fuel, and the air intake lines on the storage tanks and pipelines are protected by air filters so that the fuel is maintained at the maximum degree of cleanliness.

(*b*) *Test Methods.*—The method of utilising a test rig to give the most accurate assessment of filter efficiency is equally applicable to both rigs already described. For the sake of simplicity, however, the test method which will now be described will refer directly to the lower capacity rig (Figs. 10 and 11).

Of primary importance are the filtration properties of the filter at its rated flow. However, it is also useful to have a complete knowledge of its flow rate/pressure differential characteristics in the clean state and an indication of how they deteriorate as the filter becomes dirty. The normal procedure is therefore to establish first of all the flow rate/pressure differential characteristics, using clean fuel. Artificial contaminant is then added and the filtration efficiency is derived. Lastly, a simple measurement of dirt holding capacity is made.

(i) *Flow Efficiency.*—The test fuel is first thoroughly cleaned and dried by passing it several times through an efficient water separator placed in position F_2, Fig. 11, and then through the auxiliary filter F_1. The

water separator is then replaced by the test filter, the clean fuel is pumped through the test filter, and the pressure differentials across the unit corresponding to several rates of flow are noted. A convenient method is to start at the maximum rated flow of the filter and to reduce the flow rate in increments of 40 Imperial gallons per minute until a value of about 20 Imperial gallons per minute is reached. The flow rate is then increased in intermediate steps until the rated value of the filter is again reached.

If it is considered that the casing of the unit has a significant effect on the overall pressure differential across the unit, the magnitude of the effect is measured by repeating the flow rate/pressure differential tests with the filter elements removed from their housing.

(ii) *Filtration Efficiency.*—To determine the filtration efficiency of a filter, the unit is again installed in position F_2 in Fig. 11. The test fuel is freed from all adventitious matter by recirculating it through the auxiliary filter and the valves of the rig are then set so that the fuel is pumped at the rated flow of the test filter and follows the direction of flow indicated by the arrows in Fig. 11.

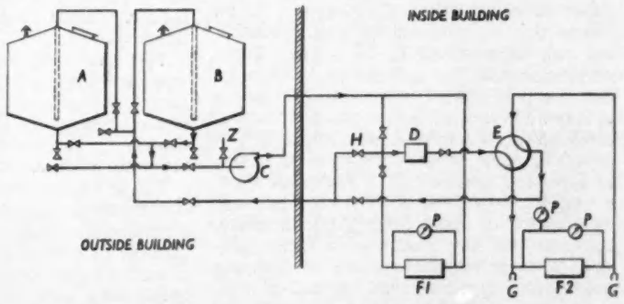
A suspension of spherical zinc particles having the particle size distribution shown in Fig. 7 is prepared in a separate circulating system. This can be fed into the rig at the suction side of the pump with the fuel recirculating in one tank but by-passing the test and auxiliary filter circuits, so that a batch of contaminated fuel is prepared for the test. An alternative method is to inject the contaminant suspension at a constant rate during the filter efficiency test, so that there is no restriction on the duration of the test run. In either case, the concentration of the suspension injected into the rig is sufficient to result in an overall concentration of approximately 30 milligrammes per litre. The feed to and effluent from the filter are sampled, representative sampling being effected by pitot-tube arrangements in regions of turbulence (Fig. 11). The contaminant in these samples is allowed to settle on to microscopic slides in the sedimentation vessels already described (Fig. 8). Dilution of the feed sample is necessary so that the concentration of particles on the slide is not too dense. When sufficient time has elapsed for all the particles to settle out, the supernatant fuel is drained away very slowly, the slides are dried, protected by cover slips and analysed as already described for the laboratory test method. The transmission curve for the filter is derived from the various transmission factors as before.

As a quick and very approximate check on the efficiency of the filter it is convenient to take samples additional to those described above and analyse them chemically for zinc content. This gives an answer in terms of milligrammes per litre of zinc in the effluent, and provides a convenient quick method of comparing filters as long as a standard contaminant is used for the feed. The rating so obtained must be treated with great reserve since no account is taken of particle sizes.

(iii) *Dirt Holding Capacity.*—It is often convenient, for the purpose of comparing filters, to determine their "dirt holding" capacities. For this purpose the valves in the rig (Fig. 11) are set so that the fuel recycles from one tank through the test filter and back into the same tank. Standard zinc contaminant is continually injected into the suction side of the pump until the differential pressure across the filter reaches a prescribed maximum level, when the test is terminated. The weight of contaminant required to give this condition is the "dirt holding" capacity of the unit.

Also of interest is the rate of clogging of the filter which is determined by plotting a graph of pressure differential versus time during the "dirt holding" test. A further test which is recommended is a check on the efficiency of the filter during the clogging test. This is conveniently done by taking samples of effluent at various times and analysing them chemically for zinc content.

(iv) *Cleaning by Back-Flushing.*—A further characteristic of certain types of filter, is that they can be cleaned by reversing the fuel flow through them. Both test rigs already described make a test of the efficiency of back-flushing simple. For example, when a filter has been blocked in the "dirt holding" test, suitable settings of the valves in the rig (Fig. 12) enable clean fuel to be pumped through the test unit in the reverse direction and then into a dump tank. The fuel flow is then returned to the normal direction and the flow rate/pressure differential characteristics of the unit are determined, as previously described. A



A, B—1000-gallon tanks.
C—Centrifugal pump.
D—Flow and throughput meter.
E—Reverse flow valve.
F1—Auxiliary filter.
F2—Test filter.
G—Sample point.
H—Control valves.
P—Pressure gauges.
Z—Contaminant injection point.

Fig. 11—Pipeline diagram of test rig : flow capacity 260 Imperial gallons per minute
Arrows indicate direction of flow during test

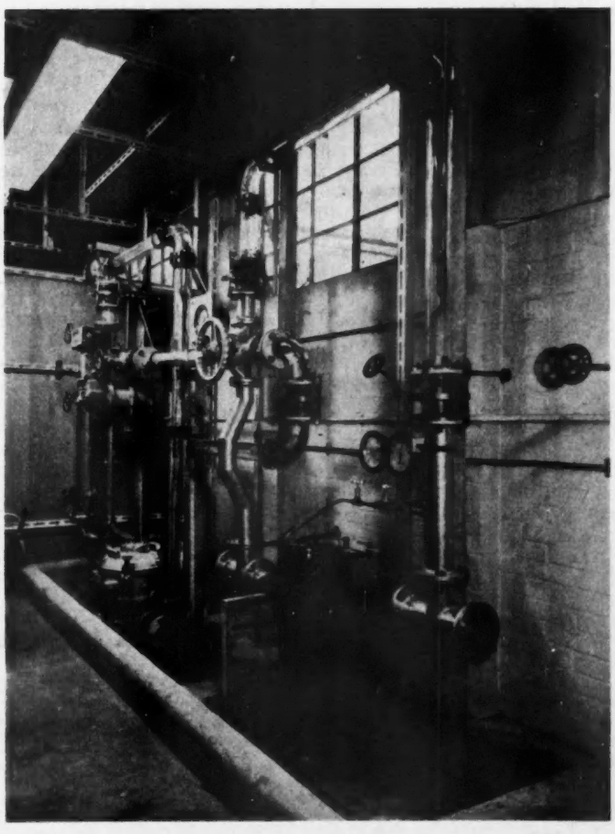
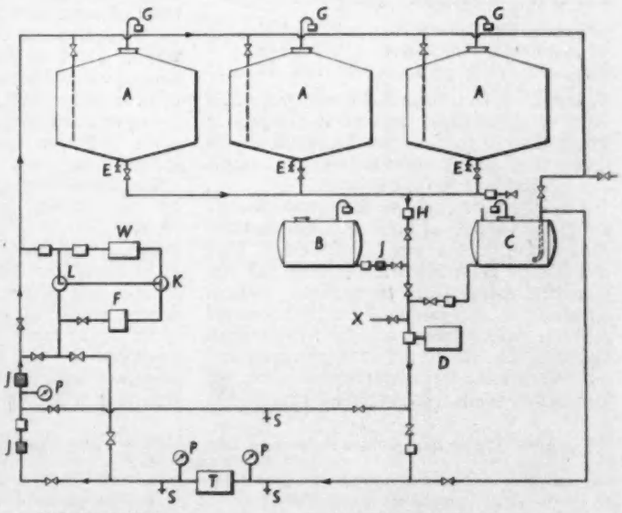


Fig. 10—Test rig (flow capacity 260 Imperial gallons per minute) : view inside test house



A—5000-gallon fuel tank.
B—1000-gallon water tank.
C—3000-gallon dump tank.
D—Pump, 500 Imperial gallons per minute.
E—Drain valve.
F—Auxiliary filter.
G—Air filter and flame trap.
H—Non-return valve.
J—Flow meter.
K—T-plug.
L—L-plug.
P—Pressure gauge.
S—Sampling point.
T—Test unit.
W—Auxiliary water separator/filter.
X—Contaminant injection point.

Fig. 12—Pipeline diagram of test rig : flow capacity 500 Imperial gallons per minute

comparison of these characteristics with those previously derived on the clean unit indicates the effectiveness of the back-flushing operation.

Significance of Results

Transmission factors have been measured for a number of materials. Effective cut-off sizes were available for five of them, and these are compared with the transmission factors in Table IV. The method, based on

Table IV—*The Transmission Factors at 5 and 10 Microns of Five Materials Rated in Order of Their Effective Cut-off Sizes*

Material	Effective cut-off size (microns)	Transmission factor	
		5 microns	10 microns
Sintered bronze (coarse)	25	0·8	0·7
Paper A	14	0·6	0·5
Nylon cloth	11	0·4	0·1
Paper B	6	0·04	0·007
Paper C	<2	0·0006	0·00009

transmission factors at 5 or 10 microns, is shown to rate these filters in a similar order to the old method, based on effective cut-off sizes. It is interesting to compare the two methods of presentation by considering, for example, papers A and B. On the basis of effective cut-off size paper B shows approximately a two-fold improvement over paper A. Now the amount of wear in an engine due to particles of any particular size can be assumed to be approximately proportional to the number of particles of that size fed to it. The transmission factors at 5 and 10 microns, for the two filters under consideration show that, as compared with paper A, paper B will reduce the wear due to 5 micron particles by a factor of more than 10, and that due to 10 micron particles by a factor of about 100. It is, therefore, apparent that the transmission factor provides a more realistic method of assessing and comparing filters than the cut-off size.

The results shown in Table V, for the

Table V—*Comparison of Transmission Factors (5 Microns) for One Layer of Paper and Two Layers in Series*

Thickness	Transmission factor	Log reciprocal transmission factor
1 layer (0·5mm)	0·038	1·53
2 layers (1·0mm)	0·0011	2·95

transmission factors at 5 microns of a single layer of filter paper and of two layers in series, tend to confirm the theoretical expectation that transmission factor is a simple exponential function of thickness.

The laboratory tests on filter materials are an important part of filter specification tests. For, although the test results on a filter unit are of great importance, their full significance cannot be appreciated without reference to the laboratory results on the medium which they utilise. Considered together, the two types of experiment not only illustrate which commercial units are satisfactory for service, but show which units can be improved upon by modifying manufacturing techniques. Table VI compares the transmission factors at the 5 and 10 micron levels of some complete filter units with the transmission factors of their filter materials. It can be seen from these results that faulty sealing in a unit can readily be highlighted and steps taken to remedy it.

Table VI—*Comparison Between Laboratory Test Results on Filter Media and Full Scale Test Results on Complete Units*

Unit	5 micron transmission factor		10 micron transmission factor		Comments
	Filter medium	Complete unit	Filter medium	Complete unit	
A	0·002	0·03	0·0001	0·002	Faulty sealing
B	0·04	0·05	0·0007	0·0005	Good sealing
C	0·0005	0·01	—	—	Faulty sealing
D	0·002	0·16	0·0001	0·045	Very poor sealing

Part III: Water Separator Tests

Basis of Method.—Much of what has already been written on filter testing also applies to water separator tests. Most commercial water separators are also fine particle filters, and their filtration efficiency has to be assessed. Many authorities advocate a combined test to determine a unit's efficiency in cleaning and drying a fuel, but such a test does not indicate its true filtration efficiency. Solid contaminants often tend to agglomerate in the presence of water, so that filtration efficiency assessments made with wet fuel result in an increase in the effective particle size of the solid particles. Such a test gives an optimistic indication of the unit's capabilities as a filter. A much more stringent test is to assess a unit as a filter, using dry fuel, and then to assess its efficiency as a water separator, using a new set of elements. On this basis, the procedure adopted for determining the flow efficiency and filtration efficiency of a water separator, follows exactly that already described for filters.

The same test rigs are used for water separator tests as for filter tests; for simplicity reference will again be made to the lower capacity rig (Figs. 10 and 11) when describing the methods of assessing water separator efficiency in the following section.

The first requirement of a water separation test is a means of obtaining a highly dispersed, reproducible emulsion of water in fuel. The passage of a water/fuel mixture through the centrifugal pump of the full-scale test rig is a satisfactory method of attaining this end. For example, a single pass of a 0·5 per cent concentration of water in kerosene produced water droplets which are mainly smaller than 6 microns, as is shown in Fig. 13.

An effective series of tests is one in which the water separating efficiency of the unit is assessed at three levels. Suitable concentrations of water in aviation fuel for these tests are 0·05, 0·5 and 3·0 per cent volume free water. The 0·05 per cent value gives a light loading of the unit and a very fine dispersion of water in fuel, the 3·0 per cent value gives a heavy water loading and a coarser dispersion, while 0·5 per cent free water gives an intermediate value.

The fuel is first cleaned of all solid matter by recirculating it through the auxiliary filter, F_1, of the test rig (Fig. 11). It is then pumped through the unit under test at its rated flow, and water is metered into the suction side of the pump at the flow rate needed to give the required concentration of water in the feed. The water/fuel emulsion produced by the pump is sampled both upstream and downstream of the water separator (Fig. 11). The sampling system is identical with that already described for filter tests, but in this case many samples are taken, at suitable time intervals, directly into the containers in which they are to be analysed.

A convenient way to estimate the water content of the fuel samples is to use the Karl Fischer titration method. This is both accurate and simple to conduct provided that the fuel samples are kept isolated from the atmosphere and are not transferred from one container to another. The Fischer method does, however, measure the total water content of the fuel, and it is necessary to know the dissolved water content of the fuel in order to calculate the free water content. Another analytical method which gives the total water content of the fuel with great accuracy by means of a quantitative chemical reaction, using volumetric technique,

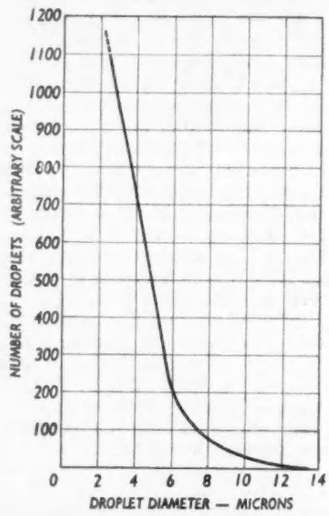


Fig. 13—Droplet size distribution of water in kerosene emulsion produced by centrifugal pump

is the pyridine-acetyl chloride method. This has a slight disadvantage compared with the Fischer method in that it takes longer to conduct.

It is sometimes argued that it is preferable to measure the free water content of the fuel directly rather than to calculate it by difference between the total and dissolved water values. It is not considered, however, that the methods at present available for free water analysis have been sufficiently developed to measure satisfactorily free water at concentrations of a few parts per million.

Some water separator cartridges have been known to include materials which could be dissolved out in aviation fuel, adversely affecting the unit's water separating characteristics. An additional quick check on fuel quality is therefore useful, to ensure that harmful materials are not leached out into the fuel.

Test Procedure.—The full sequence of tests is therefore:

(i) Filtration efficiency test.

Following this test the fuel is cleaned and new elements are fitted.

(ii) Fuel quality test.

Samples of the fuel are tested for:

(*a*) Interfacial tension against distilled water (ASTM D971);

(*b*) Water reaction (FED Test Method 3251.7);

(*c*) Gum existent (ASTM D381—steam jet);

(iii) Flow rate/pressure differential characteristics.

(iv) Water separating efficiency at 0·05 per cent water level.

All sample flasks have ground glass stoppers and are chemically clean.

Feed samples (approximately 25 ml) are taken in 50 ml flasks and analysed by the Fischer titration method. Samples are taken after 2, 10, 20 and 30 minutes' running time.

Effluent samples (approximately 100 ml) are taken in 250 ml flasks and also analysed by the Fischer titration method. Samples are taken after 2, 4, 6, 8, 10, 15, 20, 25 and 30 minutes' running time.

(v) Flow rate/pressure differential characteristics.

(vi) Water separating efficiency at 0·5 per cent water level.

Feed samples (approximately 250 ml) are taken in 500 ml flasks and analysed by the Dean and Starke distillation method (IP 74/57).

The sampling times, sample volumes and method of analysis for the effluent samples are as in (iv) above.

(vii) Flow rate/pressure differential characteristics.

(viii) Water separating efficiency at 3·0 per cent water level.

Sampling times, sample volumes and methods of analysis are as in (vi) above.

(ix) Flow rate/pressure differential characteristics.

(x) Fuel quality test.

The tests detailed in (ii) above are repeated.

At the conclusion of the tests, the elements and inside casing of the water separator are examined for damage or deterioration.

There are many items of ancillary equipment commercially available for use with water separators. As these are neither an essential part of the fundamental operation of units, nor universally required, they will not be dealt with in detail. The test rigs and analytical methods described, however, will cope adequately with the testing of such items as automatic dump valves for emptying water sumps, automatic air release valves, and fuel stop valves which are operated when a water sump becomes flooded.

General Comments

The test methods detailed above have been found to be satisfactory for assessing the suitability of filters and water separators for use in the field. It is desirable, however, that a check should be made on each unit before use and when its elements are changed, to ensure that it has been properly assembled. It is also desirable that the fuel entering an aircraft should be continuously monitored for dirt and water content, so that any possible breakdown in the fuel quality control system can be detected.

Bubble test methods for checking the assembly of a unit are available, and dirt and water monitors are at present being developed. These, it is expected, will give an immediate indication of fuel cleanliness, and act as "fail-safe" devices. The levels of trace contamination at which these devices should be triggered are not universally agreed, but it is envisaged that they will eventually be fixed at less than one part per million for solids and about five parts per million for undissolved water.

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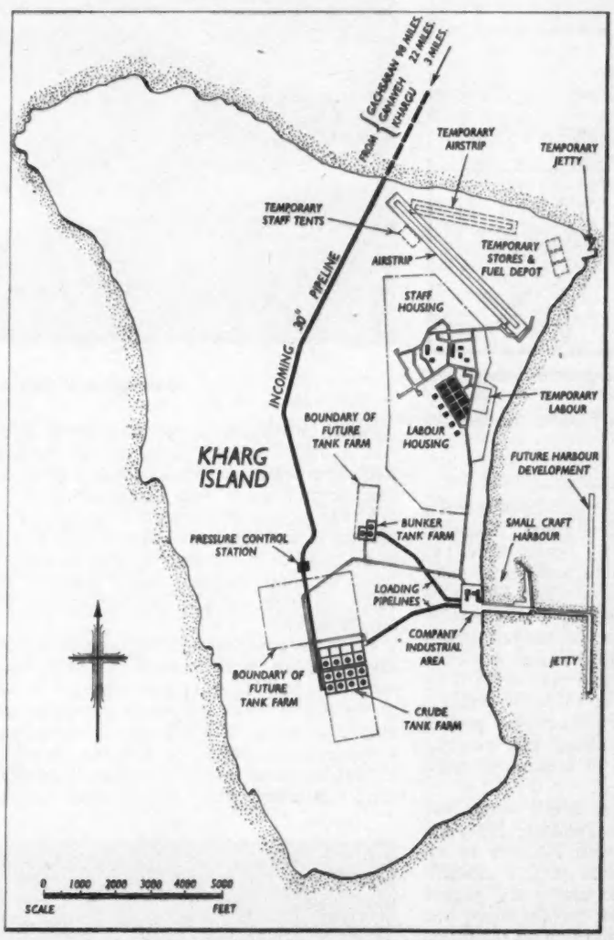
Crude Oil Terminal on Kharg Island

Expansion of the Gachsaran oil field operated by the Consortium's Iranian Oil Exploration and Producing Company pointed the need for another oil terminal in addition to the facilities at Bandar Mashur. Kharg Island was chosen as the new loading point because of the availability of deep water close inshore, and the scheme provided for the gravity loading of tankers and involved laying a pipeline from Gachsaran to Ganaveh and an undersea pipeline to Kharg. The initial capacity of this project is 330,000 barrels per day.

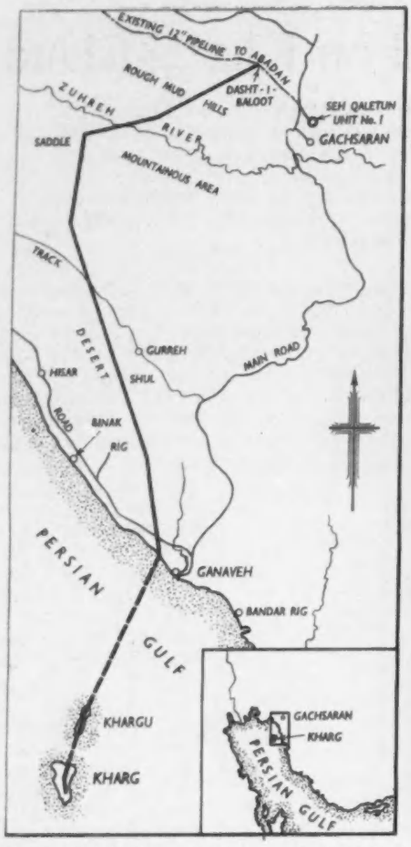
ALTHOUGH oil was known to exist in Iran in ancient times, it was not until W. K. D'Arcy was granted a sixty-year concession in 1901 that serious search for oil was begun, and it was not until after several years of fruitless effort that oil in commercial quantity was discovered in the foothills of the Zagros mountains. To exploit this find, a company, now known as the British Petroleum Company, Ltd., was formed in 1909 and a refinery built at Abadan, together with a pipeline linking it with the oil field. From this beginning there has been steady expansion, with the sinking of new wells and the discovery of new fields, combined with an expansion of the Abadan refinery and export facilities such as tank farms and loading jetties. With the opening up of new fields at Haft Kel, Gachsaran, Agha Jari, Naft Safid and Lali, production rose to a total of 31,750,000 tons in 1950 from 43,000 tons in 1912, 1,100,000 tons in 1919, 10,000,000 tons in 1937, and 17,000,000 tons in 1945. Subsequent to the nationalisation of the oil fields in 1951 and until the formation of the Consortium of eight international oil companies and its agreement with the Iranian Government in 1954, production remained at a low level. However, by 1955, production rose rapidly, attaining 16,000,000 tons in that year and nearly 40,000,000 tons by 1958. Of the latter total, 24,000,000 tons was exported via Bandar Mashur and 15,000,000 tons of crude was delivered to the refinery at Abadan, 13,000,000 for exports of products, and the remainder going to internal consumption.



Kharg Island, showing layout of facilities

To handle the increased flow from Agha Jari, additional pipelines were laid to Bandar Mashur and the capacity of the loading terminal increased. With the further development of the Gachsaran field, there arose the need to provide a suitable export outlet and it was planned to lay a pipeline to Kharg Island, despite the difficulties inherent in such a project, so that crude oil could be loaded direct into large tankers.

The Gachsaran-Kharg Island project included the development of the field by the installation of additional production units and associated facilities, electrical generation plant of 12,000kW employing gas turbines as power units, an air strip and a housing scheme. The pipeline to link the oil field with Kharg Island and of which we include a map of the route, is a 26in, 28in, 30in line having an initial capacity of 330,000 barrels per day under gravity flow from Gachsaran at 2215ft elevation to the tank farm on the island at 200ft above sea level. About 72 miles of pipeline cross foothills, rugged broken terrain and desert, to link Dasht-i-Baloot with Ganaveh on the coast of the Persian Gulf. Then there is a stretch of 19 miles of undersea line to Khargu Island and a further 3 miles of submarine line crossing the channel between Khargu and Kharg and, finally, 3 miles of land line to the island tank farm. This farm was planned to have a capacity of approximately 2,600,000 barrels and to be connected by two 36in loading lines to a four-berth jetty located on the sheltered east side of the island and having a depth of water of 60ft. Such then is the broad outline of the scheme to export crude



Route of pipeline from Gachsaran to Kharg Island

oil from the Gachsaran field to the world's markets.

Kharg Island

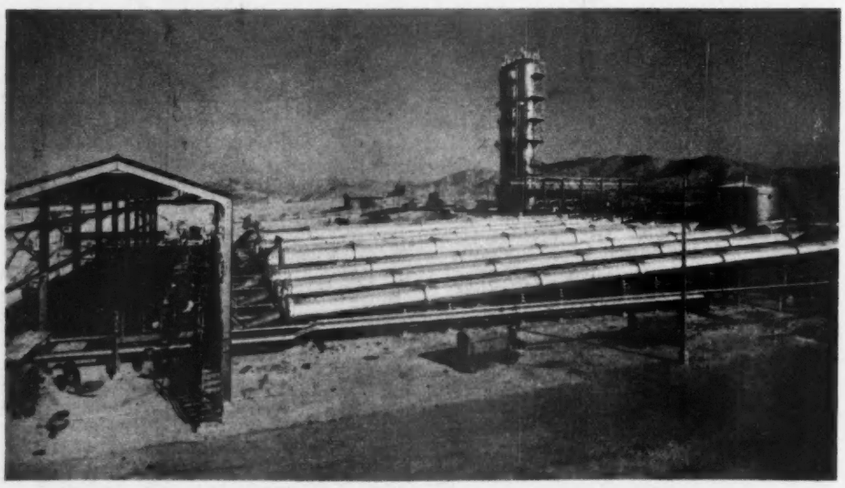
Kharg Island, chosen as the site of the new deep water oil loading terminal, measures about 5 miles in length by 2 miles wide, has an area of 8·6 square miles, and lies 22 miles off the Iranian coast and some 125 miles from Abadan. The island has a long history, attested by the presence of ancient tombs with bas-relief carvings, dating back to Alexander the Great, and was a thriving trading centre in the seventeenth century. To-day, the approval of the terminal project has once more transformed the peaceful obscurity of the island to a scene of great activity.

A temporary air strip, 3000ft long, was laid down so that from January, 1958, the island was connected with Abadan by an air service operated with D.C.3 aircraft. Helicopters were used to survey and inspect both the island and the terrain along the route of the projected land line on the mainland. A temporary jetty was built to expedite the unloading of supplies required for the construction of the terminal and a base camp set up to house the labour force under canvas. Temporary workshops were erected to enable a start to be made on the main constructional and engineering operations, while a power station, consisting of six 220kW generators driven by Paxman diesel engines and of 1320kW total capacity, was installed to meet the demand for electrical energy.

The map of Kharg Island which we reproduce, shows that the incoming 30in line crosses the island to a pressure control station and then proceeds to the tank farm located at the island's highest point, which is 200ft above sea level. At the pressure control station the static head of about 750 lb per square inch due to the hydraulic gradient from Gachsaran is reduced at capacity flow to about 35 lb per square inch. There are twelve tanks, of which eight have a diameter of 180ft by a height of 60ft and a capacity of 254,000 barrels and the remaining four each have a capacity of 140,000 barrels and measure 144ft in diameter by 48ft high. All the tanks have floating roofs and are of all-welded construction, using the shielded arc automatic system. A concrete bund contains the tanks with divisions arranged between individual tanks. At a lower level and a short distance away is the bunker tank farm which at present consists of three conical roof tanks, two being allocated to hold fuel oil and one to store diesel oil. The fuel oil tanks each hold 140,000 barrels and measure 144ft in diameter by 48ft in height, while the diesel oil tank has a diameter of 100ft, a height of 42ft and a capacity of 59,000 barrels.

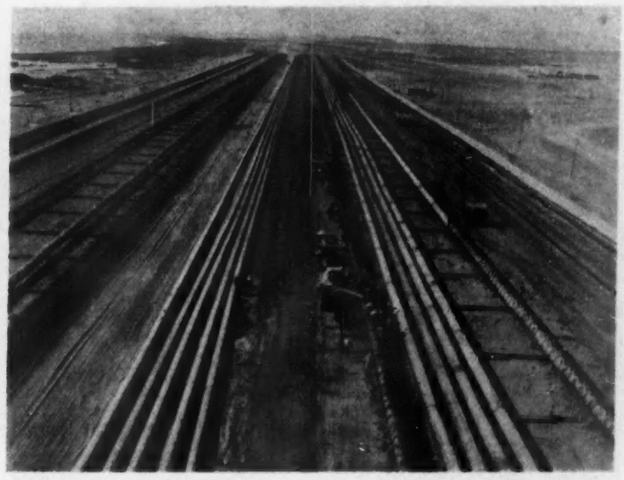
From the company's industrial area on the eastern shore there extends a 1485ft long causeway, built of stone and having a width at the top of 140ft. There is also a stone-built breakwater, of which the corresponding dimensions are 1400ft by 37ft 6in, forming a small harbour for the handling of barges, tugs, launches and other small craft, which has been dredged to a depth of 20ft. Seaward from the causeway is the main jetty having a length of 2350ft and a width of 50ft and accommodating a pipe track, a timber decked roadway, 21ft wide, carried on a steel superstructure supported by nearly 540 Rendhex No. 3 hexagonal steel piles having an average length of 125ft. At present the 120ft wide jetty head extends southwards for 2000ft, is supported by approximately 940 Rendhex No. 4 steel hexagonal piles 135ft long, and provides berths for a maximum of four ships including one of 100,000 tons deadweight, there being 60ft of water at low tide. The causeway, breakwater and jetty are seen under construction in our illustration. Loading of the tankers will be at a rate of 40,000 barrels per hour, under gravity flow, through two 36in diameter lines and will be controlled from a control operations room: the oil flow will be directed from Gachsaran, by remote control, through the pipeline, fitted with motorised valves, to the tank farm and then to the tankers. Provision has been made for automatic sampling. Other lines on the pipe track provide for handling fuel oil and diesel oil and also supplies of fresh water. To hold the latter there are two tanks 40ft high by 50ft diameter

Causeway, boat harbour and jetty under construction



Production unit at Dasht-i-Baloot

Pipe laying operations between Gachsaran and Ganaveh



Preparation of pipe strings on Khargu, showing concrete casing being applied

and having a total capacity of 30,000 barrels.

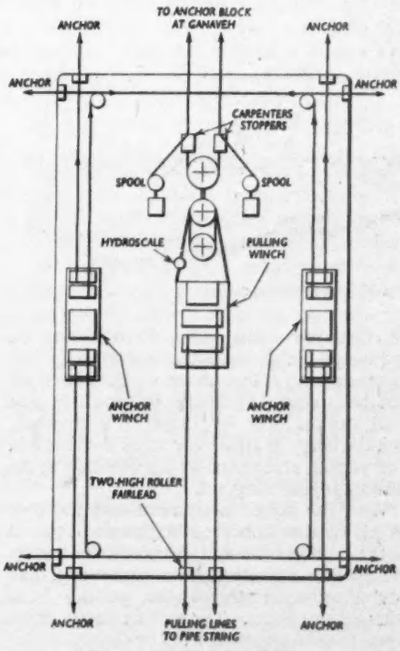
For the final ship-to-shore link, the jetty has been equipped with four banks of Chiksan hydraulic marine loading arms constructed by the Oil Well Engineering Company, Ltd., the consulting engineers being Brian D. Collins (Engineers), Ltd. Three banks consist of five station frames with five 52ft loading arms with the fourth bank having four arms. All the arms are 12in standard weight aluminium pipe of 0·375 wall thickness having a 24ft inboard section and a 28ft outboard section and being fitted with Chiksan swivel joints which provide controlled flexibility of arm movement. The rated operational condition is 150 lb per square inch and the maximum hydraulic operating pressure is 1500 lb per square inch. The maximum reach of the 52ft arm, at trunnion centre, ranges from 46ft at +20ft 4in elevation to 54ft 3in at trunnion level to 41ft at −30ft 9in elevation while the maximum drift of the boom is 30 deg. each side of centre. For working purposes the outreach is 36ft and the arm will accommodate a vertical movement of 50ft, and a fore and aft drift of 25ft. Plans provide for the jetty head to be extended when additional berthing space is required.

Concurrent with the construction of tank farms and jetty has been the building of two Richardsons Westgarth distillation plants, having a total capacity of 300,000 U.S. gallons per day, together with the necessary treatment equipment. In the permanent power station has been installed three 1064kW Brush alternators each driven by a Mirrlees Mark KSS six-cylinder turbo-charged diesel engine rated at 1508 b.h.p. and able to run on diesel fuel or Gachsaran crude oil. The alternators generate at 11,000V which is the primary distribution voltage. It was mentioned earlier that most of those employed on the project were housed in tents; however, since then, progress has been made with a housing scheme, which provides for modern and healthy living conditions, and includes prefabricated houses for married and bachelor staff. Other buildings of concrete block construction have been erected for the junior staff and the labour force. In addition there is a guest house and club, a clinic and completely equipped hospital. Other buildings include offices, workshops, garages, storage facilities, &c. Most of the quarters are air conditioned. The prefabricated units were supplied by Coseley Buildings, Ltd., and W. J. Simmons, Sons and Cooke, Ltd.

As will be noted from the map the temporary air strip is to be replaced by a permanent runway some 5000ft long by 150ft wide with shoulders 175ft in width. Another important item has been the siting and grading of a road system to provide easy means of transport from point to point for service vehicles. To-day the erstwhile small and almost deserted island has been transformed into a major oil-loading terminal for the export of Iranian crude.

Gachsaran and Ganaveh

On the mainland the No. 1 production unit at Gachsaran has been modified to increase its capacity to 150,000 barrels per day, and one additional production unit installed. One of the production units is illustrated herewith. Desulphurisation plants are now included in both units. A 12,000kW power station powered by three gas turbines has been built and a 33,000V distribution system installed. As on Kharg Island the scheme has involved the provision of an airstrip, workshop, engineering maintenance and storage facilities, offices, a housing scheme and all the amenities essential to meet the needs of the community. Meanwhile the selected route of the pipeline from Gachsaran to Ganaveh was surveyed and the right of way prepared, and the lengths of pipe were transported to the route, welded, tested, wrapped and buried over most of its length to a minimum depth of 2ft. Our illustration shows pipe laying operations between Gachsaran and Ganaveh.

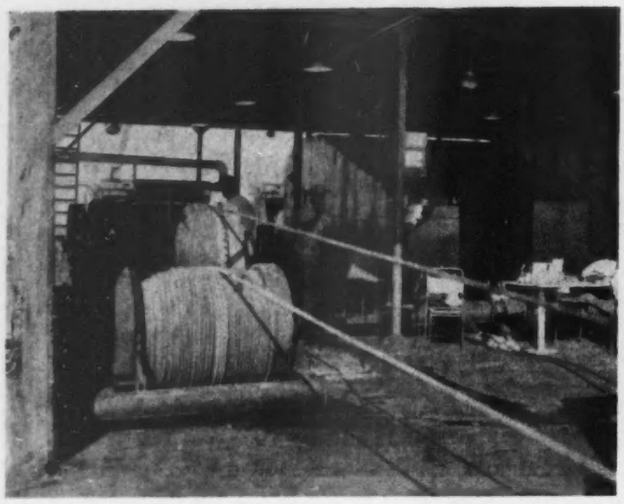


Outline arrangement of pulling barge

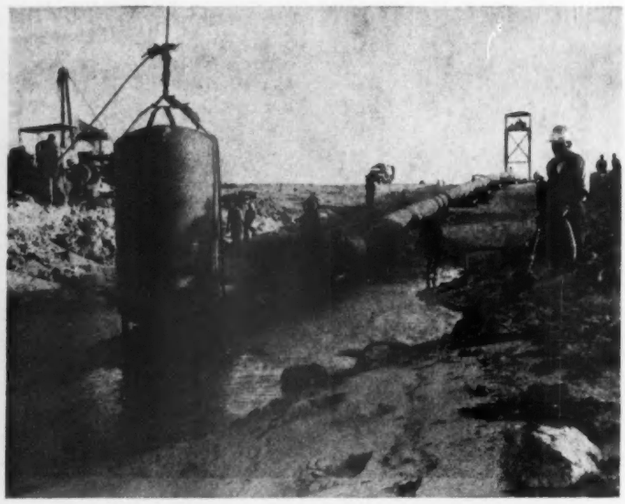
Undersea Pipeline

The most difficult part of the whole project was the linking of the Gachsaran–Ganaveh land line with the loading terminal on Kharg Island by an undersea pipeline. Initially six routes were put forward for consideration and involved a complete oceanographic study of the area, calling for : soundings to establish the contour of the sea bed ; a detailed examination of the sea floor by geologists and the analysis of rock and soil samples ; an examination of sea organisms ; the charting of the direction and speed of currents and tidal action together with data related to weather conditions. An evaluation of all these factors broadly indicated the route to be adopted and the final line was decided upon after a careful check of the route had been made. With a maximum depth of water of 160ft, and the possibility of the generation of waves up to 10ft from crest to trough, and the need to avoid any excessive stresses being set up in the pipe by currents, choppy water and ground swells, it was fairly evident that the only method of laying the pipe was by the continuous pull system.

With this decision made by the firm carrying out the work, International Marine Constructors C.A., an affiliate of Collins Construction Company, a camp was established on Khargu Island. This is a low-lying sandy strip, 3·4 miles long by 1·3 miles wide, having an area of 1·1 square miles and separated from Kharg by a strait about 3 miles wide. Materials and equipment were transported to the island and landed at an improvised jetty and work commenced on the fabrication of the strings of pipe. The 30in o.d. pipe, of Italian manufacture, is seamless and has a wall thickness of 0·5in, and was delivered in 26ft lengths. These were welded into strings, three measuring 4400ft in length for the Khargu-Kharg section and twenty-five at 4000ft in length for the long pull to Ganaveh. All welds were 100 per cent X-rayed using the Travel-Ray equipment which is capable of



Pulling barge showing anchor winch on left and pulling winch on right

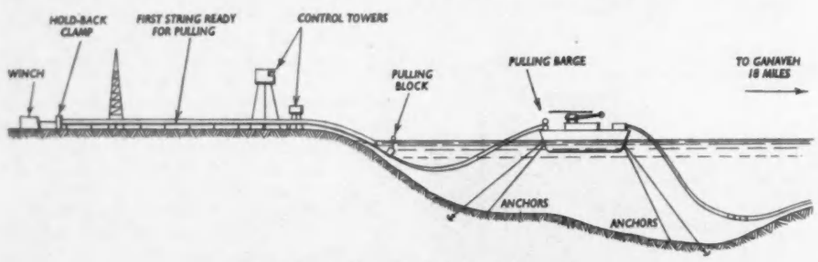


Pulling-head of pipe string entering water

inspecting 40ft of pipe a minute and of examining up to 2000ft of pipe in a single continuous operation. Each string was hydraulically tested up to 1260 lb per square inch, and given a "Bitumastic" covering of one coat of primer and two of enamel followed by two inner wraps of glass fibre and an outer wrap of thermo glass. Finally the whole string was covered with concrete 2·5in thick and reinforced by a 4in by 4in by 10 gauge wire mesh, and then placed on racks to allow the concrete casing to cure and harden. The strength of the pipe is adequate to withstand the stresses set by having to span a distance of 70ft. In our illustration can be seen pipe strings being prepared and the protective concrete layer being applied.

The thickness of the concrete applied was determined by the amount of negative buoyancy required for the pipe when being pulled, and as prepared the pipe and coverings weighed 445 lb per foot, or about 800 tons per string, and had a negative buoyancy of 4 lb per foot run. This latter figure was increased to 20 lb per foot negative buoyancy by the addition of concrete saddle weight where it was necessary to counter the effects of currents. Concurrent with the fabrication of the pipe strings, the launching arrangements were put in hand. Launching ramps were dredged and the coral reef blasted, to ensure that the pipe entered the sea at a controlled radius, and special support units, mounting twelve rubber-tyred wheels in sets of three, were placed at 40ft intervals over the length of the string. Anchor blocks were placed in position on the mainland, and on Khargu the hold back winch was sited and also a hold back block for the standing cables. Control of the pulling operations was by radio from towers erected on Khargu and at Ganaveh, and also by light signals. The other major item of equipment was the pulling barge which is fitted with a Seamaster pulling winch, capable of exerting a pull of 1,000,000 lb and powered by a diesel engine driving through a torque converter, two spools and a dynamometer and anchor winches. We reproduce a diagrammatic arrangement of the barge and also a view of one of the anchor winches and the pulling winch.

In preparation for a launching a pipe string is transferred from the racks to the launching cradles by tractors and a pulling head welded to the seaward end. Attached to the head is a large diameter pulling sheave fitted with a buoyancy chamber measuring about 5ft diameter by 8ft high. Twin wires pass from the sheave to the winch on the pulling barge. To the landward end of the string is fastened a hold back clamp which is attached through a block to the hold back winch capable of exerting a restraining pull of up to 10 tons as directed from the control tower. The barge now backs off from the shore to a specified distance, paying out the 2in diameter pulling cable, and is navigated to its correct position along the line of pull by radio through a Tellurometer system of triangulation, there being two stations on the Ganaveh shore and a third station on the barge. Eight anchors, operated by two diesel-driven four-drum double-ended winches, hold the barge in position and twin cables, held by carpenter's stoppers, link the barge to an anchor block at Ganaveh. The pulling arrangements are outlined in the accompanying diagram.



Diagrammatic layout of pulling arrangements

With the barge in position and the pipe string on the launching bogies and secured to the pulling head and the hold back winch, the pulling operations can commence, and our illustration shows the pulling head entering the water. The pulling winch exerts a pull to the amount ordered by the controller, who also relays load instructions to the hold back winch so that the pipe will be under the exact degree of tension required to prevent it from slipping out of control and to maintain a straight line axis between barge and shore. When, near the end of each pull, the landward end of the pipe reaches a particular point, another set of cables are shackled to the hold back clamp and pass through a connection at a hold back concrete block land anchor. The pull continues until these cables are taking a predetermined strain. The pull is stopped and the cables to the hold back winch are released, leaving the pipe held by the standing hold back cables. A tension of about 40,000 lb is maintained in the pipe when not being pulled.

The next pipe string is now rolled into position on the launch ways, lined up and welded to the preceding string, then the joint is wrapped and covered after the weld has been checked. Meanwhile, the hold back clamp has been connected to the landward end of the new string and attached to the hold back block and winch, and the standing cables released. During the pipeline tie-in operations the barge has raised anchors and moved further off shore, a distance equal to the length of a pipe string, to a new pulling position and has spooled in a similar length of the cables leading to the Ganaveh shore. When all these preparations have been completed, the next pull is ready to begin and the control tower radios revised load instructions to the operators on the barge and hold back winch. The foregoing procedure is repeated for the launching of each pipe string and the whole operation is co-ordinated under direction from the control tower. The pulling of the 19 miles of 30in pipeline from Khargu to Ganaveh was completed by the end of last year.

Main Contractors

Bredero Bouwbedrijf, N.V., housing, ice plant, crushing plant, roads, sewers, culverts, foundations for tanks, bundwalls and power station, sleepers and anchor blocks for pipelines; Werkspoor N.V., lighting and power, tanks, temporary and permanent power stations, water pipelines; Richard Costain (M.E.), Ltd., temporary jetty, material handling, small boat harbour fill; Raymond International-Costain, jetty; Constructors John Brown, Ltd., evaporation plants; Williams Brothers-Constructors John Brown, Ltd., Gachsaran-Ganaveh pipeline; Overseas Dredging Company, Ltd., dredging small boat harbour; International Marine Constructors C.A., Ganaveh-Kharg pipeline.

Centrifugal Pump Dimensional Standardisation

DRAFT STANDARDS FOR END-SUCTION AND HORIZONTAL SPLIT CASING PUMPS

Communicated by the Engineering Equipment Users Association

FOR a long time the Engineering Equipment Users Association has been concerned by the total lack of simple dimensional standards for centrifugal pumps. A thorough study of the subject has been made and as a result the Association has produced two simple draft standards for limited ranges of end-suction and horizontal split-casing pumps. These drafts only deal with overall and fixing dimensions and their object is to ensure that all makes can be readily interchanged. The dimensions proposed in the drafts were prepared after examining a large number of existing makes. The drafts have been submitted to the British Standards Institution with a request that they should be considered as a basis on which standardisation might be initiated.

The handling of fluids is of major importance in many industrial processes, and the dimensional standardisation of the pumps used to deal with them is felt by the Association to be long overdue. Speed and efficiency are important in the design and construction of new installations, particularly those involving large capital investment. Dimensionally standardised equipment is essential to ensure early completion and operation.

At present the leading external dimensions (especially the fixing dimensions) of centrifugal pumps intended for similar duties differ with the make. Design work on piping and on pump foundations cannot be finished, therefore, until the pumps are ordered and until dimensioned arrangement drawings have been received. Further delays may occur while awaiting the certified driving motor drawings required to enable bed-plate details to be completed for the combined unit. Thus, delays in pipe fabrication and construction of pump foundations become inevitable and cause production losses quite disproportionate to the capital value of the equipment involved.

A large proportion of the pump manufacturers' total output is undoubtedly taken by small users mainly concerned with replacements or modification of existing plants but the same delays still occur and are often more troublesome. For example, it may be found in some cases that an old unit is no longer made or that a replacement is difficult to obtain ; a faulty pump may need immediate replacement to maintain production and if an identical unit is not readily available time is lost while pipe work connections and new fixings to existing foundations are made. Such alterations are always wasteful and are, for example, particularly objectionable in the mining industry.

The use of dimensionally standardised pumps which could be easily interchanged or replaced would avoid these alterations and delays. The non-existence of such pumps now entails the stocking of spare units, and the tying-up of capital which this involves. The establishment of external dimensional standards for centrifugal pumps need have no marked effect upon performance, although a guaranteed minimum performance figure would be desirable. On the other hand, such standards would enable all makes of pump having the same rating and speed to be readily interchanged and the stocking of spares to be reduced. The only variants would be perhaps unimportant differences in the hydraulic characteristics and internal construction.

It has been contended that many of the difficulties mentioned above can be overcome if an individual buyer selects one manufacturer as his sole supplier of pumps. This, however, leaves him entirely dependent on one manufacturer. If that manufacturer proves unable to meet a required delivery date it may disrupt a whole programme.

It has also been said, mainly by those unfamiliar with the advantages of proper standardisation, that dimensional standardisation can retard progress by restricting competition and the development of improved designs. Experience has proved that this contention is unsound. For example, in the United Kingdom, British Standards of benefit to both the manufacturer and the user have been issued for the leading external dimensions of totally-enclosed fan-cooled electric motors (B.S. 2083) as well as for worm gear units (B.S. 3027) ; steps to extend the range of equipment covered by these standards are already under consideration. Nearly all the heat exchangers used in the American oil industry are made to standards drawn up in collaboration with the Tubular Heat Exchanger Manufacturers Association.

The first moves towards any standardisation are always difficult, but after the subsequent benefits become apparent, further progress follows. An immediate changeover to dimensionally standardised pumps would be impracticable for either the manufacturer or the user. The more progressive firms would endeavour, however, to make the change quickly and would secure advantages before those who were slower to do so. Manufacturers, if they so wished, could certainly promote an early changeover by offering some inducement to those who were prepared to accept the standardised pumps.

All users and pump manufacturers are therefore urged by the Association to collaborate through the medium of the British Standards Institution to draw up these essential dimensional specifications. The subsequent provision of a range of standard pumps in accordance with the resulting British Standards will remove one further restriction on industrial efficiency.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

ELECTRICALLY CONDUCTING RUBBER FLOORING

No. 3187 : 1959. Price 4s. The accumulation of static electricity is a serious hazard in places such as explosive works and hospital operating theatres, and the right sort of flooring is an important factor in the safe discharge of this electricity to earth. Rubber flooring for a variety of these special purposes laid down in the new standard can be made suitable by the incorporation of materials such as carbon black, and then resistivities down to 1 ohm cm can be obtained. The specification puts an upper limit on the permitted electrical resistance (50,000 ohms) but no lower limit, and makes the important proviso that where this type of flooring is in use, all wiring and controls must be outside the zone of risk, and portable electric equipment and flexible connections prohibited. Thus there is no possibility of electric shock or fire from the good earth the flooring provides.

The publication deals with all the factors necessary to make such electrically-conducting floors safe and durable : composition, workmanship, dimensions, resistance limits, hardness, &c. Standard methods of test and sampling are given, together with the method of earthing. Sheets of rubber flooring which comply with the standard must be marked on the back with a continuous red line, the manufacturer's identification and the number of the standard. Manufacturers may, if they wish, be licensed to apply the Kite-mark to flooring that is to B.S. 3187.

In some cases a rubber flooring is needed which is also conductive enough to disperse static charges, but sufficiently resistive as well to limit safely any leakage current from the electrical installation. This is properly called " anti-static " flooring and must have both upper and lower limits of resistance clearly defined ; a further British Standard to cover these requirements is in preparation.

GEAR HOBS

No. 2062 : 1959. Part 1 : Hobs for general purposes 1 D.P. to 20 D.P. inclusive. Price 8s. 6d. Changing conditions have called for a replanning of the standard on " Gear Hobs," first published in 1953, and Part 1 of the revision has just been published. This specification is limited to 1 to 20 D.P. inclusive, and the tooth form and pitches given are in agreement with International Standards Organisation recommendations Nos. R.53 and 54 (in drafting the revision as a whole, account has been taken of recent work by the I.S.O. and of current American specifications).

A new high grade of hob included is comparable in accuracy with the grade AA for marine hobs. Hobs of this grade of accuracy have been found necessary when cutting gears to the fine limits now called for in various specifications. Limiting parallel arbor dimensions are recommended in an appendix, so that correct fitting conditions between hob and arbor can be obtained.

The presentation of the tables of permissible errors shows typical methods of test for each element and follows similar lines to other recent British Standards for gem cutting tools.

COMPARISON OF BRITISH AND OVERSEAS STANDARDS FOR STEELS

No. 3179 : 1959. Part 1 : Chemical composition of wrought carbon steels. Price 6s. Ready comparison can now be made between British Standards and American (S.A.E.) and German (D.I.N.) specifications for the compositions of wrought carbon steels with this newly-published set of tables. The tables have been issued by the British Standards Institution to meet the demand of both manufacturers and users of steel. For easy reference, Part 1 lists the steels in ascending order of maximum carbon content, thus bringing, as far as possible, similar compositions into close proximity. The British Standard, S.A.E. and D.I.N. numbers are given, with the type of product for which the steel is used, its carbon, silicon, manganese, sulphur and phosphorus contents and any additional information in a " remarks " column.

This publication is the first part of a series of comparison tables authorised by the Iron and Steel Industry Standards Committee and prepared in collaboration with the British Iron and Steel Federation in order to meet a demand for a concise form of comparison between British and overseas standards. Part 2 of this standard, dealing with the chemical compositions of alloy steels, will be issued shortly, and a further table or tables based on tensile properties will follow.

LITERATURE

Steelmaking for Steelmakers. By A. JACKSON. The United Steel Companies, Ltd., 17, Westbourne Road, Sheffield, 10. Price 40s.

THIS is the kind of book an engineer delights to find. It contains the teachings of a lifetime of practical experience in many branches of steelmaking. In reviewing these clearly printed pages we recall with pleasure the obvious frank respect and friendliness shown by all his staff to the author, when he guided visitors through his works. He had well earned that respect from the men in the works because thirty-five years ago he served as a shift chemist, for both fixed and for tilting steelmaking furnaces, and so gained first-hand, round-the-clock, day-in day-out practical experience of those essential but dangerous processes, where any playing with fire might be fatal. To that practical experience he added, by study at Sheffield University, for which he was awarded an Associateship in Metallurgy, an ability to describe what he saw and measured quantitatively. Consequently he has written twenty or more technical papers, and gained much wider recognition, both through the Iron and Steel Institute and as Works Manager. He was appointed Technical Adviser on Steelmaking to the United Steel Companies, Ltd., in 1958. Some of the present book is the third printing of some of the text matter, which first appeared as a series of articles in *Men and Metal* from April, 1949 to October, 1952. Then as a second appearance these articles were reprinted by the Appleby-Frodingham Steel Company in December, 1952.

For thirty years the author shared his knowledge with others in lecturing to evening school students and technical societies. Thus it came about that it was a member of the Appleby-Frodingham Melting Shops Metallurgical Society who suggested the original wider circulation in *Men and Metal*, the journal of the Iron and Steel Trades Confederation. Each month some four pages, about 2000 words, were published. These could be read in a quarter of an hour, but they were based on the half-hour talks, which were usually followed by an equally long discussion. Thus the main part of the book had taken form by 1952, but a further two articles were added in June, 1958.

The author's philosophy is admirably suited to the interesting and varied occupation of steelmaking, where thought as well as experience is constantly needed, and above all confidence in one's own ability, and this can surely only come with knowledge. Hence this book deserves to go as a treasured friend into the homes of those sturdy men who actually make steel, in the heat and noise of the melting shops ; the melters, ladlemen, teemers, chemists and others who help them in their skilled teamwork.

Details in the production of the book deserve praise : the careful choice and good reproduction of the forty-three line drawings and photographs will be at once appreciated. There are unintentional errors such as Institute instead of Institution, at the top of page viii, but these will not trouble many readers.

The twenty-seven chapters cover 225 pages and are followed by an Appendix of terminology, facts and figures. Then as an Addendum before the final index, an easily understood illustrated guide to simple physics and chemistry, has been inserted and forms the final twenty-ninth chapter. It is part of the Appleby-Frodingham Junior Works Course for young operatives and many older men will read it with pleasure.

The chapter on " Oxygen for Steelmaking " could scarcely be more firmly based because the author's works have been successful pioneers in this new development. He concludes that one must apply oxygen to make steel at very much higher rates of production. One must invent methods of applying it so that one retains or even improves the traditional close control over the quality of the product.

In THE ENGINEER for October 9, 1959, we reviewed a book on *Practical Ironmaking* which was published by the same steelmaking company. That book was written for those engaged in making pig iron ; iron which is the basis for steelmaking. These two books are clearly complementary in the field of practical knowledge and deserve to be widely read.

Windscale ; Problems of Civil Construction and Maintenance. By STUART SINCLAIR, M.I.C.W. George Newnes, Ltd., Tower House, Southampton Street, Strand, London, W.C.2. Price 25s.

THE author is a clerk of works at Windscale, where he has been concerned with day-to-day problems of construction and maintenance since the early days of its construction. The book is addressed principally to those interested in the constructional work at an establishment such as Windscale, but the general reader will find much interest in it, for the account given is very readable, and never too complex to be readily followed. Furthermore, its tendency is to explain established processes, such as grouting, for example, which a more severe technical treatise would take for granted. Thus students of civil engineering will find that the book gives a useful background to the special problems of nuclear power construction.

The special problems encountered in building the Windscale reactor, as Mr. Sinclair describes, included the construction of chimneys of unparalleled magnitude, and elaborate effluent pipelines. Special maintenance problems included complicated remedial works to the biological shields, and the introduction of a supply of cooling air to an internal void, for which a new technique for drilling into reinforced concrete was evolved.

Adhesives Guide. By JOYCE HURD, B.Sc. British Scientific Instrument Research Association, Southill, Elmstead Woods, Chislehurst, Kent. Price 20s.

As a result of numerous inquiries for information about adhesives received by the Association, it was decided to compile a comprehensive list of the adhesives commercially available in Great Britain. The book now published gives details of adhesives based upon particulars provided by British manufacturers, as well as much other useful information on the subject.

A section dealing with the choice of adhesives for various materials is followed by an encyclopædia of the basic types of adhesives compiled from published material in text books and articles in the technical press. The trade section first classifies manufacturers by the basic types of adhesive they make and then gives lists of manufacturers' products and their properties, method of use and main uses. A useful appendix gives the recipes for a number of well-known adhesives as well as some of the Association's own development.

All firms which use adhesives to any large extent will find this guide a very useful addition to their reference library in that it provides much essential information as well as the sources of supply which are not always readily obtainable.

Lieu des racines d'une équation algébrique dépendant d'un paramètre : Application à la stabilite et au guidage des fusées. By FRANCISQUE SALLES. Publications Scientifiques et Techniques du Ministère de l'Air, No. 351. Paris : Magasin C.T.O., 2, Avenue de la Porte-d'Issy, Paris (15e). Price Fr.1810.

THE paper falls into three main sections. In the first the author discusses the locus on the complex plane of the roots of an algebraic equation with a single parameter, and gives a practical method for tracing this locus. Two examples are given, selected from the field of servo-mechanisms and from hydrodynamics. The methods which have been developed are applied, in the second section, to the study of the stability of a stabilised and guided rocket flying in a vertical direction.

Finally, an example is given of the numerical integration, by the method of finite differences, of a system of differential equations with variable coefficients, such as occur in connection with guided missiles.

Books Received

Analytical Elements of Mechanics. Vol. I. By T. R. Kane. Academic Press, 111 Fifth Avenue, New York 3, N.Y., U.S.A. Price 4.75 dollars.

Rubber to Metal Bonding. Second Edition. By S. Buchan. Crosby Lockwood and Son, Ltd., 26, Old Brompton Road, London, S.W.7. Price 42s.

An Introduction to the Dynamics of Framed Structures. By Grover L. Rogers. Chapman and Hall, Ltd., 37, Essex Street, London, W.C.2. Price 82s.

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THE ENGINEER

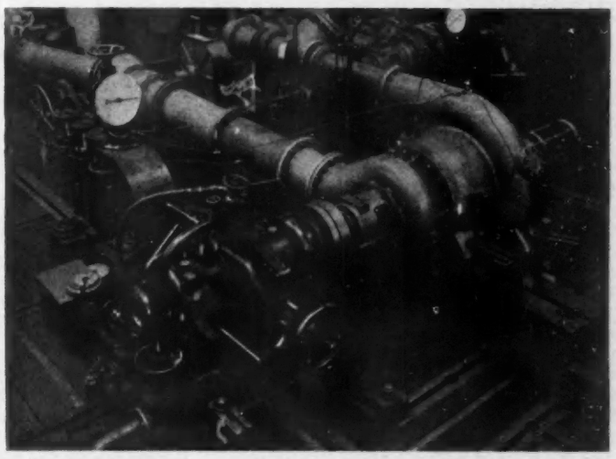
Technical Contributors Section

FEBRUARY 1960

Pump/Turbine Investigations

By R. A. STRUB*

As the importance of pumped-storage for large-scale power supply systems grows, increasing interest is being taken in reversible machines which may be operated either as turbines or pumps. Sulzer Brothers, who have been builders of storage pumps for many years, have made investigations into reversible pumps, and the results of their work are set forth here, together with the conclusions drawn. A comparison of radial, mixed-flow and axial machines operating either as pumps or turbines is made, and the fields of application of these designs are outlined. The article closes with a brief survey of the methods of starting and shutting-down reversible units and of the problem of control.



LABORATORY tests have been conducted by the author's firm on several models of reversible pump/turbine machines to study the characteristics of these machines and investigate the varied working conditions encountered in their practical application in pumped-storage hydro-electric schemes. The problems raised by reversible machines, however, are not restricted to the pump/turbine proper. They also involve other equipment, such as the motor-generators and valves, as well as the operations of starting, stopping and synchronisation. There is, further, the question of whether it is admissible to dispense with the turbine governor, since no governor is required for the pump. There can be no doubt, however, that interesting applications await reversible machines if the designer and the plant engineer can contrive to make full use of their advantages, and, above all, of the plant simplifications which they offer.

The maximum relative velocity of water to blades is approximately equal for a pump and a turbine operating at the same head per stage. However, a comparison of the head per stage normally permitted for a storage pump with that of a turbine of the same peripheral speed shows that the head exploited in a turbine wheel is approximately twice that attainable in a pump stage. This is due to the fact that a turbine can operate with appreciably higher blade loads than a pump; for an acceleration of flow takes place in its guide vanes, whereas in a pump the water is decelerated and there is a possibility of separation of flow. The back pressure needed to preclude cavitation, which is higher for a pump than for a turbine, is another factor influencing the head per stage. Basically, there is no objection to increasing the head per stage for a pump of given specific speed by raising the speed of rotation, provided that an adequate suction pressure is available and the material of the pump has the necessary mechanical strength and resistance to erosion.

The only comparative characteristic value as a function of the specific speed, and the only basis of comparison for a pump and a turbine, is consequently the pressure coefficient $\psi = 2gH/u^2$, which represents the loading of the blades. In the light of these remarks, we can now draw up the following list, which shows that there is no absolute correspondence between the machine types operating under identical conditions in a storage and a peak-load power station.

Turbine	Pump
Pelton	Multi-stage radial
Slow-running Francis	Two-stage radial
Fast-running Francis	Single-stage radial
Slow-running Kaplan	Mixed flow or multi-stage axial
Fast-running Kaplan	Axial

The relation between turbines and pumps, moreover, is affected by the available back pressure, a higher pressure permitting the choice of a pump of higher specific speed.

There is basically no obstacle to using a pump impeller as a turbine wheel, provided that, for the same head and number of revolutions per minute, its rotor diameter is made approximately $\sqrt{2}$ times as large. As will be seen later, the efficiency of such a turbine may even be extremely good. The converse, however, is not true, as the flow channels in the turbine when working as a pump have too much divergence, thus impairing the efficiency.

In combined storage and peak-load power stations the reversible machine is especially interesting, for heads between 400m and 600m (say, 1300ft and 2000ft). In this range the Francis turbine would often have too low a specific speed, and the Pelton turbine an unduly high one, leading to a machine with six nozzles. The two-stage or three-stage pump/turbine neatly fills this gap in the duty range.

Characteristics of the Pump/Turbine

The following definitions and notation are used:

Head coefficient $\psi = 2gH/u^2$.

Flow coefficient $\phi_n = Q/F \cdot u$ (at constant speed).

$\phi_H = Q/F \cdot \sqrt{2gH}$ (at constant head).

* Sulzer Brothers, Ltd., Winterthur.

Power coefficient $\lambda_n=\phi_n \cdot \psi/\eta$ pump (at constant speed).
$\lambda_n=\phi_n \cdot \psi \cdot \eta$ turbine (at constant speed).
$\lambda_H=\phi_H \cdot \eta$ turbine (at constant head).

Speed coefficient $\nu=1/\sqrt{\psi}=u/\sqrt{2gH}$.

Specific speed $n_s=3{\cdot}65n\sqrt{Q}/H^{3/4}$, where $Q=m^3$/sec., $H=m.$, $n=$r.p.m.

or

$$\sigma=2\phi^{1/2}\left(\frac{b}{D_m}\right)^{1/2}\Big/\psi^{3/4}.$$

Furthermore,

$$\phi_H=\nu\phi_n=\frac{1}{\sqrt{\psi}}\cdot\phi_n\ ;\ \lambda_H=\lambda_n\nu^3=\lambda_n/\psi^{3/2}$$

The definitions of F and u are given in Fig. 1.

A series of tests was carried out on various models which had been constructed primarily for use as pumps. The illustration (page 343) shows a three-stage model pump in experimental operation as a turbine, the output of 350 b.h.p. being absorbed by the hydraulic brake shown in the left foreground. Fig. 2 is a section through the machine. The characteristics for both directions of rotation of radial, mixed-flow and axial pumps with fixed blades are given in Figs. 3, 4 and 5. Figs. 6 and 7 show, in diagrams of a type more familiar to the turbine designer, the results obtained with a pump/turbine having a specific speed of approximately 100. In radial, mixed-flow and axial machines the following points are noted :

(*a*) The optimum efficiency of the machine when operating as a turbine is somewhat lower than its efficiency as a pump, although, in machines of low specific speed, it may also be somewhat higher.

(*b*) The optimum efficiency as a turbine is obtained at a head 15 to 50 per cent in excess of that of the pump. Consequently, the optimum efficiency is attained simultaneously in pump and turbine operation when the speed of the turbine is 7 to 25 per cent below that of the pump.

(*c*) At equal heads the power developed by the machine operating as a turbine is somewhat lower than the power absorbed when operating as a pump.

(*d*) The runaway speed is lower in turbine operation than that of the classical turbine. The ratio of the runaway speed n_0 to the normal speed n at a given head ψ is fixed by the relationship

$$\frac{n_0}{n}=\sqrt{\frac{\psi}{\psi_0}}.$$

The definition of these values is given in Fig. 3.

It is interesting to note that, when the machine is working at its optimum efficiency as a pump, the turbine operates too far to the left of its peak efficiency. The efficiency loss increases at lower heads. If, on the contrary, the head rises too much, the delivery of the pump decreases rapidly. In turbine operation, however, the efficiency improves at first and then drops slowly as the head increases. It is clear from this that the reversible machine is not very suitable for big fluctuations of head. The conventional arrangement with separate pump and turbine is for that matter not a great deal better, the limitation in the direction of high heads being due to the pump. In extreme cases it is therefore necessary to have recourse to two speeds in order to be able to deliver over the whole range of heads. The undesirable shift of the characteristics for pump and turbine operation is no doubt the main disadvantage of reversible machines. A number of measures designed to improve this feature will be discussed later.

Tests carried out on six single-stage or multi-stage model pumps with specific speeds between 80 and 800 showed that the relative position of pump and turbine characteristics is always similar. In the case of radial machines the efficiency proved to be higher for the turbine than for the pump.

In multi-stage pumps operating as turbines the energy remaining after the last stage is very small in relation to the total energy. It is therefore unnecessary to provide a special diffuser at the outlet of the machine. In a single-stage pump/turbine, on the other hand, this component must be very carefully designed. A turbine elbow diffuser causes a comparatively small deceleration, and in pump operation consequently only a slight acceleration, which is often not sufficient to provide good velocity distribution at the impeller inlet. The diffuser therefore requires particularly careful study in reversible machines for low heads if it is to be effective in both directions of flow.

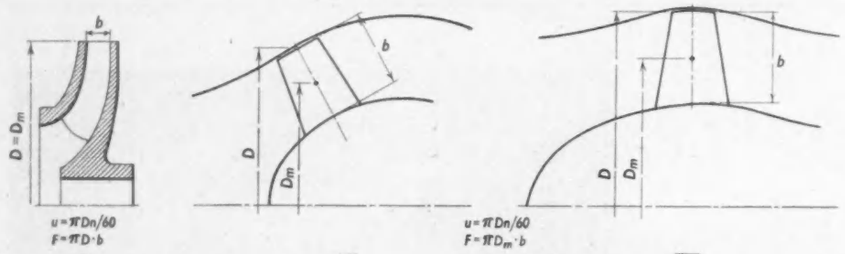


Fig. 1—Definition of F and u

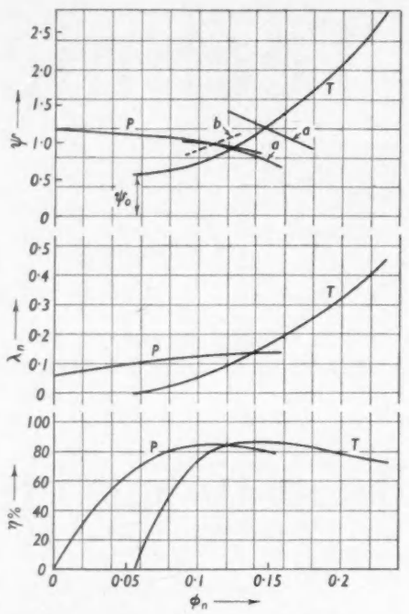


Fig. 3—Characteristics of a pump/turbine as a function of the flow at constant speed ($n_s=100$)

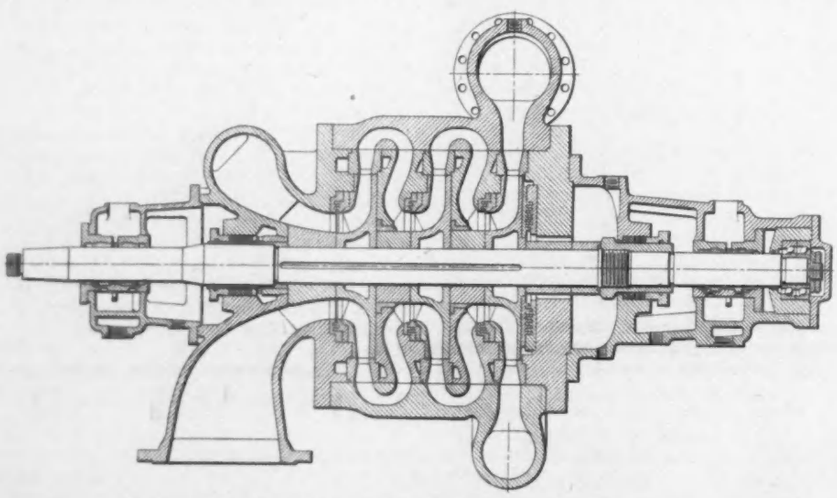


Fig. 2—Section through the three-stage pump/turbine

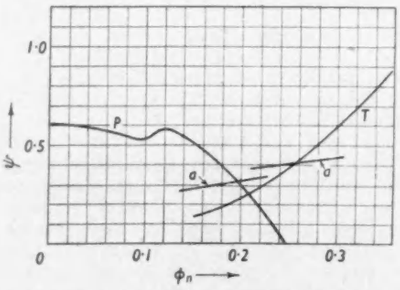
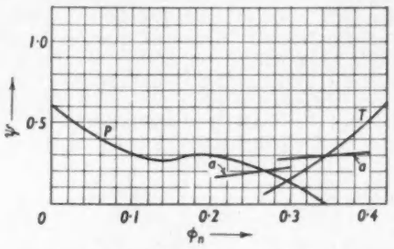


Fig. 4—Head-flow characteristics of a pump/turbine at constant speed ($n_s=550$)

Fig. 8 gives an interesting presentation of the rates of flow in turbine operation as a function of speed. In machines with low specific speeds the flow falls off fairly rapidly when the runaway speed is approached. This reduction of flow tends to disappear as the specific speed rises, and for machines of



a—Locus of maximum efficiencies with adjustable runner blades.

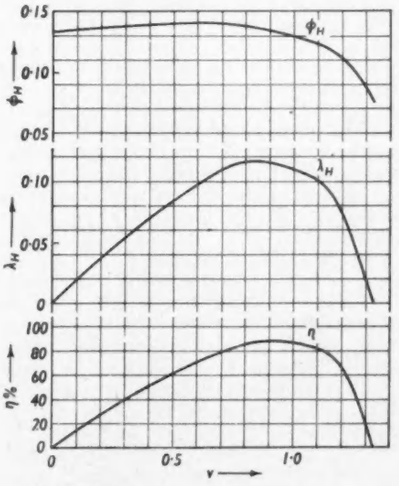
Fig. 5—Head-flow characteristics of a pump/turbine at constant speed (n_s=800)

high specific speed ($n_s \approx 500$) the situation is reversed. The diagram shows once more that the ratio of the runaway to the service speed increases with increasing specific speed.

Effect of Two Speeds or Adjustable Blades

There are several methods of counteracting the relative shift of the pump and turbine characteristics :

(*a*) The choice of different speeds for pump and turbine operation permits the position of the characteristics to be altered at will, so as to obtain the best efficiency for both modes of operation. There are certain cases of pump operation in which a considerable fluctuation of the discharge head (as,



ν = Speed coefficient.
φ_H, λ_H, η—Flow, power, efficiency at constant head (non-dimensional coefficients).

Fig. 6—Characteristics of a pump/turbine in turbine operation as a function of speed at constant head (n_s=100)

for instance, when the station lies at the foot of a dam) imposes the use of two driving speeds. In this case the aim will be to make the speed change in pump and turbine operation at the same static head. In this way it is possible to avoid changing the speed in the transition zone of the delivery head every time pumping or generating is done. As Fig. 9 shows, this procedure involves a certain loss of efficiency ; the best solution would require a speed change at a head *d* in turbine and at a head *b* in pump operation. If the periods of operation as pump or turbine are not very long, a continual speed change in a certain range of heads may be a serious obstacle to this method of adaptation.

When the machine is switched over to the higher speed, the delivery of the pump rises considerably, so that it may be necessary to throttle the flow so as to reduce delivery temporarily in order to avoid the danger of cavitation or unduly high suction pressure. A noteworthy fact is that a reduction of the turbine speed at a given head causes an increase in the flow and in the power generated.

The speed step must not be chosen with reference to efficiency only, but must also permit the simplest possible design of the motor generator. Either pole-changing machines or those with two stator windings might be employed.

(*b*) In radial reversible machines the adaptation of the pump and turbine characteristics can be partially achieved by the use

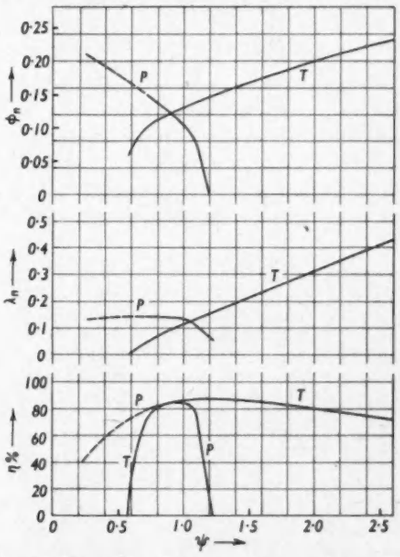
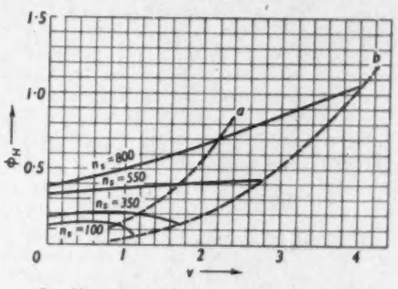


Fig. 7—Characteristics of a pump/turbine as a function of the head at constant speed (n_s=100). The symbols are as in Fig. 5

of a guide wheel with adjustable vanes. In Fig. 3 two curves are shown, in addition to the characteristics of a radial machine with fixed guide vanes running as a pump and a turbine, to show the locus of the maximum efficiencies when the guide vanes are adjustable. It will be evident from these curves that the use of adjustable guide vanes is of no great interest in pump operation. In turbine operation, on the other hand, an improvement is possible by opening the guide vanes at low heads and closing them as the head increases. As the efficiency drop with increasing head is only gradual, the use of adjustable guide vanes is particularly useful at comparatively low heads, when the efficiency is improved and the power output increased appreciably.

As already mentioned, the choice of two speeds is often unavoidable for the pump when the fluctuations of the head are very marked, since the use of adjustable guide vanes does not solve this problem. On the other hand, adjustable guide vanes are not always justified for small variations of head, since they complicate the machine. It should also be pointed out here that the guide vanes must be rigidly fixed during pumping in order to prevent vibration, and this again makes for a fairly complex mechanical design.

One means of improving the pump efficiency as a function of the discharge head which would also enable pronounced head fluctuations to be mastered would be to adjust the diameter of the impeller and the blade outlet angle. This, however, would involve complicated impeller design. And it should also be considered that this measure would result in a substantial increase in



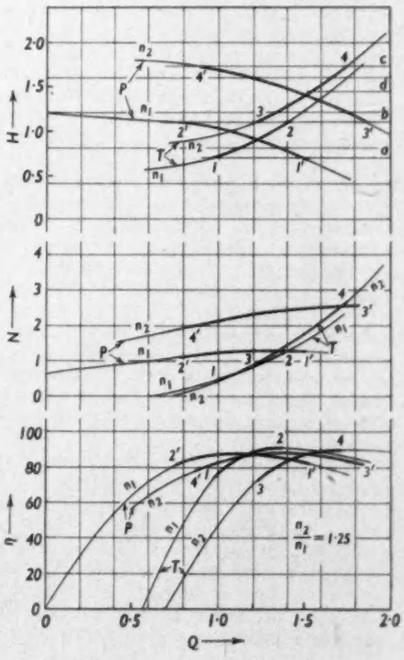
a—Speed in pump operation.
b—Runaway speed in turbine operation for a head corresponding to optimum efficiency in pump operation.
ν = Speed coefficient.

Fig. 8—Flow-speed characteristics of a pump/turbine operating as a turbine at constant head

power requirements with rising discharge head, since the delivery quantity would also necessarily be increased.

(*c*) In mixed-flow pump/turbines adjustable runner blades are to be preferred, for their effect on efficiency is considerably greater than that of adjustable guide vanes. Fig. 4, in which the locus of optimum efficiency is entered for various positions of adjustable runner blades, shows that it is an advantage as regards efficiency both in pump and in turbine operation to close the runner blades as soon as the head falls off and to open them when the head increases. The result of this is that the flow and the power absorbed in pump operation increase rapidly with rising heads and diminish with falling heads, which is not always acceptable.

(*d*) The observations made in relation to mixed-flow machines also apply to axial



N—Power.
H—Manometric head.
Q—Flow.
The figures characterise the limiting points of operation for the lower level (*a*) and upper level (*c*).
b–*d*—Levels corresponding to change of speed.

Fig. 9—Characteristics for two different speeds

units. The slope of the locus of maximum efficiencies, however, is here somewhat gentler. This slope becomes steeper with decreasing specific speed. Fig. 5 shows the relative position of the characteristics.

It is obvious that adjustable guide and runner blades, together with variable speeds, permit much more accurate adaptation of reversible machines to the working conditions. The main object in using such machines, however, is to simplify the plant, and if the machine itself were complicated unduly this end would clearly not be attained. For this reason very simple designs must be given serious consideration even if they involve certain concessions in the way of efficiency and adaptability.

Starting the Machine

The pump is started directly with the generator operating as an asynchronous motor. As soon as the maximum speed is reached, the motor is excited and synchronised. There are two methods of keeping starting current and starting power low, one being applicable to radial and the other to axial machines :

(*a*) Introduction of compressed air into the casing, so that the impeller turns in air.

(*b*) Closing of the adjustable runner blades in axial or mixed-flow machines, then opening them again when the normal speed is reached until the discharge pressure is exceeded, and finally opening the discharge valve.

When the unit is switched over from pump to turbine operation, the reverse procedure is followed and the unit then shut down. Starting the machine as a turbine presents no difficulties. The valve on the pressure side is opened slowly till the speed is just below the synchronous speed. The motor-generator is now switched on without excitation and furnishes the small amount of power required for the remaining speed increase. When the steady state is reached, the motor-generator is excited and synchronisation can take place.

Another alternative is to use a by-pass at the pressure valve for fine adjustment of the flow in order to bring the unit up to the synchronous speed, or—in the case of axial and mixed-flow machines—to regulate the speed up to synchronisation with the adjustable runner blades. Switching on to the grid is then effected as with a normal turbine set. The starting operations consequently do not call for a guide wheel with adjustable vanes either in pump or turbine service.

The change-over from pumping to power generation can also be made very quickly by allowing the set to run backwards after the motor has been switched off, the valve opening being limited so that the synchronous speed in the reverse direction is not exceeded. After this first phase, the motor-generator can be connected to the grid. If the valve is opened slowly, connection to the grid can even take place without limiting the valve opening.

An interesting way of solving both the problems of starting and regulation of a power station equipped with several pump/turbines is to install a separate unit comprising a normal turbine and generator which can be used for diminishing the power steps when putting pumping or generating units into operation or for starting the reversible machines at variable frequency.

Control

Opinions still differ on the question of the governing of reversible machines operating as turbines. Habits of thought derived from familiarity with conventional turbines often lead to the view that reversible machines must also be governed, and the fear is entertained that trouble might be encountered in the grid in the event of excessive frequency fluctuations due to the absence of turbine control.

Yet when it is considered that the starting or stopping of storage pumps even to-day may often cause abrupt power demands or gains of as much as several hundred megawatts, which are accepted without qualms, it is not quite clear why similar load fluctuations in turbine service must necessarily be controlled. Since the starting or shutting-down of a turbine affects the supply system in exactly the same way as the shutting-down or starting of a pump, there is every justification for asking why reversible machines should not be allowed to operate as turbines without the provision of any means of control.

In the large interconnected supply grids which are common to-day, it should in any case be permissible to run many reversible machines without the provision of governing equipment. Frequency control in the mains can safely be left to the normal turbine plants which are fitted with governors. Only if this fact is recognised can full benefit be derived from the main advantage of reversible machines, which is their simplicity.

Simplified Design of Anti-Vibration Foundations for Drop Hammers

By W. EASTWOOD, B.Eng., Ph.D., A.M.I.C.E., A.M.I.Struct.E.

The object of this article is to present a simplified procedure for the construction of anti-vibration foundations for drop hammers in cases where ground conditions are reasonably good. It should be noted that the simplified procedure should not be applied to pneumatic hammers which have out-of-balance rotating and reciprocating parts in addition to the ram. In such cases special precautions may be necessary to avoid excessive rotational vibrations.

Basis of Design

THE first essential of the sprung foundation in its simplest form is that there should be an adequate inertia block beneath the anvil. As will be seen in the example worked later, this results in the kinetic energy of the anvil and the interia block, as they move downwards after the blow, being much reduced. The second important factor is that the springs should have a stiffness very much less than that of the ground. This will ensure that most of the kinetic energy of the inertia block and anvil is absorbed by the deformation of the springs rather than the ground. At the end of the downward swing the whole of the kinetic energy has been converted to strain energy which is divided between the ground and the springs, approximately in the inverse ratio of their stiffnesses. The softer the springs the smaller the amount of energy transmitted to the soil.

It may well be thought that introducing a spring which is very much softer than the ground will result in considerable "liveliness" of the anvil and inertia block. This need not be so as will be seen from the following calculation which refers to a Massey 15-cwt ram-type double-acting steam drop hammer. It is assumed that the ground has good bearing properties and that a concrete inertia block the same size as that recommended by Messrs. Massey for a traditional foundation is to be used. This block is 11ft by 8ft 3in in plan, and weighs about 40 tons. The elastic properties of "good" ground vary widely, and for a given soil the settlement to be expected under a given load per square foot increases as the plan area of the foundation increases. In the present example it will be assumed that the inertia block is to be placed in a concrete-lined pit of external dimensions 15ft 6in by 12ft 6in and that for a base of this size the elastic settlement of the ground under a static load of 60 tons would be $^1/_{64}$in. This corresponds to an elastic deflection of 1in when the pressure on the base is approximately 300 lb per square inch, which is within the range to be expected for good ground. It should be noted that the first few times the ground is loaded, the settlement might be considerably greater than $^1/_{64}$in, as part of the deflection will be plastic. Even the elastic part of the settlement is likely to be greater than $^1/_{64}$in at first. Eventually, after sufficient loadings, the plastic deformation will become negligible, and the elastic constant will have reached its equilibrium value.

The total blow energy is given in Messrs. Massey's catalogue as 9·4 ton-foot, and the total falling weight (including, say, 6 cwt for the top die) is 25 cwt. Thus, the velocity at the moment of impact to give a total kinetic energy of 9·4 ton-foot will be about 21·9ft per second and the total momentum will be $21{\cdot}9\times1\frac{1}{4}=27{\cdot}4$ (ton-foot-per-second units).

By the law of conservation of momentum this momentum will be shared after impact between the falling weight and the anvil block and inertia block. The falling weight may bounce, of course, depending on the kind of forging and the state of the work. In the present calculations it is assumed that there is no bounce, but the calculations are made in exactly the same way if there is bounce, and they yield exactly similar results as far as the relative "liveliness" of the sprung foundation to the unsprung is concerned. If there is no bounce, the falling weight continues to move downwards after impact with the same velocity as the inertia block and anvil. The total weight moving downward will now be approximately 60 tons, as the anvil weighs rather less than 20 tons. For a total momentum of 27·4 ton-foot-per-second units the velocity immediately after impact will be 0·456ft per second. Thus, the total kinetic energy after impact will be

$$\frac{60\times0{\cdot}456^2}{2g}=0{\cdot}192\text{ft ton}=2{\cdot}31\text{in tons.}$$

Suppose that the inertia block stands on springs which deflect, say, 0·25in under the static load of 60 tons. The stiffness of the springs will be 240 tons per inch. Together with the ground, which has a stiffness of

$60\times64=3840$ tons per inch, we have two springs in series, the combined stiffness of which is given by the well-known formula :

$$\frac{1}{F}=\frac{1}{F_1}+\frac{1}{F_2}=\frac{1}{240}+\frac{1}{3840}.$$

The stiffness of the two in series is thus 226 tons per inch and the total settlement under static load

$$\frac{60}{226}=0\cdot266\text{in.}$$

As is well known, when a mass rests on a linear spring, the vibrations ensuing from a displacement of the mass are simple harmonic of frequency given by

$$N=\frac{P}{2\pi}=\frac{1}{2\pi}\sqrt{\frac{g}{\Delta}}$$

where N is the number of cycles per second and Δ is the static deflection of the spring. The maximum velocity of the vibrations is given by $p\delta$ where δ is the amplitude of the vibrations. In the present instance we know that $\Delta=0\cdot266\text{in}=0\cdot0222\text{ft}$, so that $p=38\cdot1$. Putting $38\cdot1=0\cdot456$ft per second (the downward velocity of the inertia block calculated above) gives $\delta=0\cdot142$in. This is the total dynamic deflection of the springs plus the ground. It is shared between them in the inverse ratio of their stiffness so that the springs will deflect

$$\frac{3840}{240+3840}\times0\cdot142=0\cdot134\text{ in}$$

and the ground will deflect by

$$\frac{240}{240+3840}\times0\cdot142=0\cdot008\text{ in}$$

Measurements have shown that the maximum deflection of the springs is very close to the values given by a calculation of this kind.

There are, of course, additional movements and deformations within the anvil and inertia block due to the stress waves set up by the impact. The amount of energy in these stress waves can be very large. In the example, the kinetic energy was reduced from 9·4 ton-foot before impact to 0·192 ton-foot after impact. The difference between these two represents energy used in deforming the work and in setting up stress waves. The initial compression wave travelling down through the anvil and inertia block will result in a reduction in depth which will be superposed on the compression of the springs. However, the maximum compression of the springs will not take place until perhaps 0·03 second after impact. In this time the stress waves in the concrete will have been reflected up and down many times and will have been considerably damped out. Thus, the two effects are not fully superposed on each other.

It is interesting to consider what would happen to this same foundation if no springs were used other than the ground. The ground stiffness would be 3840 tons per inch. as before, and the corresponding value of p would be 157·5. Thus, the value of amplitude corresponding to the peak velocity of 0·456ft per second would be 0·035in. All of this would be in the ground and is nearly five times as great as the ground deflection when the springs are used.

It should be mentioned that, whilst the calculations using the principle of conservation of momentum are valid for the spring-mounted block they are only an approximation when the block is mounted directly on the ground. When there are no soft springs to intervene part of the energy of the stress wave in the concrete inertia block will pass through to the ground. This stress wave will often have penetrated a foot or two into the ground during the small instant of time that the tup and the anvil are in contact (it will not have penetrated far since the velocity of a stress wave in soil is small compared with that in concrete). Thus an indeterminate part of the ground beneath as well as part of the ground in contact with the sides will be acting as part of the inertia block. But the effect of this will not be such as to invalidate the general conclusions regarding the reduction of ground deformations when springs are used.

The importance of a sufficiently large inertia block if movements are not to become excessive can be seen from the following. Suppose that the inertia block and anvil had only weighed 30 tons instead of 60 tons. For the same momentum after the blow the velocity of the inertia mass would be doubled. Since the velocity is doubled but the mass is halved the kinetic energy, $\frac{1}{2}MV^2$ will be twice as big as before. Further, for a given static deflection of the springs the stiffness will be only half the previous value. Thus, to absorb double the energy, the dynamic deflection will be about twice as large. This would be excessive, possibly resulting in troubles such as fracture of holding down bolts or even parts of the hammer frame. Generally, the author thinks that the size of the inertia block recommended by the manufacturers for a traditional foundation will be suitable also for mounting on springs. However, it should be stressed that this is a minimum size ; when possible it should be increased.

Changing the stiffness of the springs does not have a proportionate effect on the magnitude of the dynamic deflection. The deflection is inversely proportional to the square root of the combined stiffness of the spring and ground. Thus doubling the spring stiffness results in only 30 to 40 per cent decrease in the dynamic deflection.

The dynamic force in the springs and on the ground will be reduced, of course, by using less stiff springs. The dynamic force in the 240 tons per inch springs (i.e. $\frac{1}{4}$in static deflection) would be $0\cdot134\times240=32$ tons, whilst for the 120 tons per inch springs it would be $0\cdot193\times120=23$ tons. Both these values are small compared with the static load of 60 tons on which they are superposed. The calculation for the corresponding dynamic load on the ground when the inertia block is not supported by springs is less precise, of course, but the dynamic load will be of the order of 130 tons or more. A repeated dynamic load of this magnitude will often result in excessive settlement or tilting of the foundation.

Possibility of Resonance with Ground

Much has been written previously concerning the possibility of the natural frequency of the hammer foundation on its spring coinciding with that of the ground, thus causing resonance and build-up of the amplitude of vibration. Most of the discussions on this point have been based on two misconceptions.

First, it has been frequently stated that each type of ground or each site has a unique natural frequency of oscillation. Over twenty years ago Lorenz and others published the results of tests made by the Degebo organisation in Germany. In these tests an oscillator was mounted on a heavy plate which rested on the ground. The oscillator generated an up-and-down out-of-balance force, the frequency of which could be varied up to just over 30 c/s. As the speed of the oscillator was increased it was found that resonant vibrations were set up at a frequency which depended on the kind of soil. These frequencies have been widely quoted, particularly by Crockett,[1] as being the natural frequencies for the various types of ground. In fact, of course, the resonant frequency obtained with an oscillator of the Degebo type on any particular soil will vary very widely with the size of the base and the total weight of the base and oscillator. The resonant frequency can be reduced by either increasing the area of the base plate or increasing its mass per unit area, and vice versa. This has been demonstrated experimentally by the author[2] using a single blow to generate the vibrations, and by Arnold, Bycroft and Warburton[3] using a vibrator of the Degebo type. The variation of resonant frequency with the foundation size and load is so great that the Degebo results are quite meaningless in this context. They should not be quoted as giving the natural frequencies of various kinds of ground.

That there can be no such thing as a unique natural frequency for the ground can be seen by comparing it with the air above the ground. To all intents and purposes the air is also a semi-infinite elastic medium. Sound waves of any frequency can be generated in the air by using say, a voice, or a musical instrument, or, say, the impact of two objects. If an explosion such as a gun shot is used it may well be that for guns of approximately the same size a sound of approximately the same frequency will be obtained. But this is not "the natural frequency" of the air. Similarly, the frequency obtained by letting off an explosive charge in the ground or dropping a weight is not the "natural frequency of the ground."

In the case of a sprung foundation the dynamic load is applied to the ground through a soft spring at a relatively slow speed as the inertia block moves downwards. Since the increase in pressure on the ground is small and is applied slowly, there is no reason at all to expect the frequency of the ensuing vibrations in the ground to be in any way related to those obtained with a plate vibrator, or an explosive charge, or by dropping a weight directly on to the ground, except perhaps fortuitously.

To sum up then, the ground at any particular site does not have a unique "natural frequency" but can vibrate with almost any frequency. The actual frequency of waves emanating from a hammer base will be a function of the hammer blow, the size of the foundation and the load on it, and will be modified by the use of springs.

A second misconception which has often appeared in previous writings is that if the natural frequency of a hammer on its springs has the same value as that of the ground, resonance will occur and the vibrations will build up. For example, the Absorbit Company[4] have said "The principles of shock and vibration isolation for hammers are in fact now well known .... Briefly it is necessary to provide the foundation with a natural vibration frequency well below the natural frequency of the ground." Two other authors, using only slightly different wording appear to have implied the same thing in saying that "The hammer blow sets up a shock wave which travels through the whole system and will cause it to vibrate, each part, including the subsoil, vibrating at its own natural frequency. Should any two parts happen to have the same natural frequency vibration will then be in resonance and may build up to a considerable amplitude."

As stated earlier there is no such thing as a unique natural frequency of the ground, but even if there were, resonant build-up could not occur unless some external driving

force was applied. Consider again the example of the 15 cwt double-acting drop hammer. The total kinetic energy of the inertia block and anvil when moving downwards immediately after the hammer blow was shown to be 0·192 ton foot. If the oscillation of the inertia block on its springs excites vibrations in the ground the kinetic energy will be shared with the ground. Thus instead of the oscillation of the inertia block building up it will be reduced. Further, each wave emanating outwards in the ground generally represents a complete loss of energy in the system because the waves are not normally reflected back. Thus a so-called resonant system would result in a very rapid decrease in the exuberance of the vibrations.

Nevertheless there is a possibility of resonance of a different kind. If the natural frequency of the inertia block and anvil on their springs were exactly "n" times that of the hammer blows it would be possible to build up the energy in the vibrating system since the hammer blow would always occur on the downward swing of the inertia block. However, this effect should not produce serious vibration build-up in practice. First, the blows are unlikely to occur at absolutely uniform time intervals. Because of the relatively high frequency of the vibration compared with the blow frequency, quite small variations in the time intervals between blows will obviate resonance. Further, damping will generally be inherent to a considerable extent in the vibrating system or can be specially provided (these matters are dealt with later). This will severely limit the vibrations even under conditions of complete resonance.

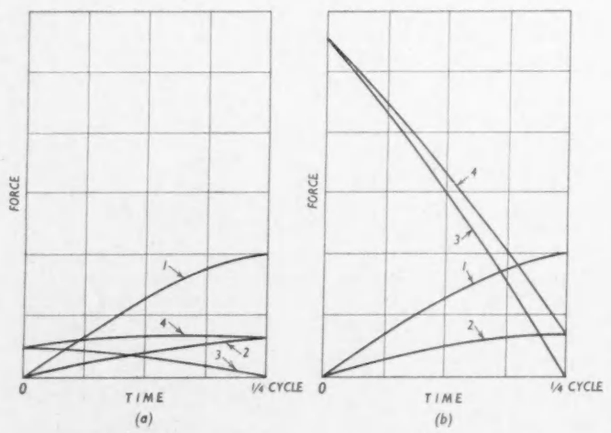
The above can be summarised, therefore, by saying (*a*) there is no such thing as a unique natural frequency of a site; (*b*) the measuring of the frequency of waves caused by, say, dropping a weight or letting off an explosive charge will not give advance information about the frequency of waves which will be generated by a hammer mounted on springs; (*c*) even if the ground vibrations were of the same frequency as the natural frequency of the inertia block there would be no build up of vibrations since the total internal energy of the system cannot grow without external stimulation; (*d*) the only real possibility of resonant vibration build-up for the whole hammer occurs when the frequency of the inertia block on its springs is an exact multiple of that of the hammer blows. This is unlikely to happen provided the natural frequency of the inertia block is high, compared with that of the hammer blows. Even if it did happen the build-up of the vibrations would be severely limited by damping.

Necessity for Damping

It is absolutely imperative that somewhere in the vibrating system there should be a means of dissipating the kinetic energy in order to prevent the possibility of build-up of the vibrations if the frequency of the hammer blow was a sub-multiple of the frequency of vibration on the springs.

Provided the springs are not too soft a considerable part of the strain energy in each deflection will be in the ground. Damping is quite high in the soil, and in addition some of the energy imparted to the ground takes the form of Rayleigh waves spreading outwards. All this energy is completely lost to the system. Thus, provided the springs are not too soft, with static deflections of the order of 0·25in, say, the ground will usually take care of damping.

However, objection may be raised that this damping is only obtained provided a not insignificant part of the energy of the vibration, say, 10 per cent at least, is allowed to enter the ground. It may be desirable under some circumstances to have such soft springs that the energy transmitted to the ground is negligible. In that case dampers would have to be incorporated. However, it should be realised that in many cases the dampers will defeat the purpose of putting in the very soft springs. On the downward swing of the inertia block the damping force on it acts upwards. Consequently, the force on the dampers acts downwards and is transmitted to the ground. If the damping is to be at all strong, this force may be greater than the force which would have been exerted by using a stronger spring and letting the ground do the damping. This fact seems to have been overlooked by some previous workers. For example, Crockett[1] has recently written: "Anvils with exceptionally soft springs need dampers—nearly dead beat. This gives least live load to the ground and reduces the vibration to the utmost." In the case of dead beat damping, the vibration is virtually damped out in the course of one downward swing and return. Taking again the example of the 15 cwt double-acting hammer it will be found that if it were on very soft springs with a static deflection of 1in, the dynamic deflection would be 0·28in. However, with dead beat damping, the total movement could not exceed about 0·28in in the upward and downward swing. To absorb 2·31 ton-inch of work in a total movement of only 0·28in would necessitate a frictional damping force of 8·5 tons. If the damping were viscous the peak value would be even higher perhaps more than 20 tons, and it would occur on the downward swing. But with no dampers, the dynamic peak load would have been $0{\cdot}28\times60=16{\cdot}8$ tons. Further, this peak load of 16·8 tons would be built up slowly throughout the downward deflection of the springs, whereas the damping force is built up to a maximum very rapidly in the small time during which the inertia block is being set in motion by the hammer blow. Thus, the undamped system would probably give a much smaller shock to the ground than the "dead beat" damped system.



Vertical scale used in (*a*) is twice that in (*b*). Line 1 is force in spring and on ground with no damping, line 2 is force in spring with damping, line 3 is damping force and line 4 is force on ground with damping (i.e. 2+3).

Spring and damping forces (*a*) according to Absorbit, Ltd., and (*b*) author's version

Absorbit, Ltd.,[4] has also discussed damping. To illustrate the effects of damping, the firm used a diagram similar to Fig. 1 (*a*). It said that in this diagram line 1 represents the force in the undamped spring. When damping is introduced the same spring is compressed by a smaller amount so that line 2 represents the force in it. Line 3 is said to be the damping force, so that the total force on the foundation, the sum of lines 2 and 3 will be line 4. The peak value of line 4, as shown, is much less than the peak value of line 1. In fact, the lines should be more like those in Fig. 1 (*b*). If the compression of the springs on the first downward swing is reduced by approximately two-thirds by the damping, as would appear from a comparison of lines 1 and 2, the energy absorbed by the springs on the downward swing would only be 0·11 of the kinetic energy and the other 0·89 would be absorbed by the dampers. Referring again to the example of the 15 cwt double-acting hammer, the energy absorbed would be 2·05 ton-inch in a movement of 0·047in. Taking the peak value of the damping to be approximately twice the average, the value will be about 85 tons. This compares with a peak force of only 32 tons when no dampers are used.

Often the use of dampers will lead to some increase in the dynamic load on the ground, therefore, and this load is introduced much more rapidly than when the springs are undamped. Often the dampers should be regarded as suppressors of amplitude rather than dynamic load.

In the author's opinion, the use of dampers can be avoided in most installations provided a little of the energy, say, 10 per cent or, preferably, 20 per cent, can be allowed to enter the ground. Where the very highest insulation of the foundation is required, dampers may have to be used, but under these circumstances it is desirable that they should only act on the upward swing. It should also be mentioned that a number of instances of breakage of dampers have been reported.

Vibrations Other Than Vertical

Crockett and Absorbit, Ltd., have both warned against only considering vertical vibrations. They have stressed that the hammer can oscillate in any of six ways (six degrees of freedom as they are called). These consist of vertical oscillations, horizontal oscillations in either of two directions at right angles to each other, and rotational oscillations about any of three mutually perpendicular axes, one of which is vertical. However, three of these modes of vibration are not possible with a drop hammer. The only disturbing force is the hammer blow which is vertical. This vertical blow cannot cause either a purely horizontal vibration or rotational oscillation about the vertical axes. But it can cause rocking about the two horizontal axes if the blow is struck off-centre, as it inevitably will be. Fortunately, the eccentricity of blow will not generally be big enough to impart a large angular momentum to the inertia block and anvil, and the springs which insulate the ground from vertical shock will also insulate it against the rocking movement.

It should be remembered, however, that

in most cases the natural frequency of rotational vibration will be appreciably less than that of purely vertical oscillation, and there will be a greater possibility of resonance with the hammer blow, particularly if very soft springs are used. For example, springs with a deflection under the static load of, say, 0·8in, give a vertical natural frequency of just over 200 c.p.m. The natural frequency of rocking may be, say, 120 c.p.m., and some small power hammers work at about this speed. Low-deflection springs with a much higher natural frequency are obviously desirable in such cases.

Alternatively, the natural frequency of rotational vibrations can be reduced by placing springs, which have a very high compression resistance but low shearing resistance, between the sides of the inertia block and the sides of the pit. There are available multi-plate rubber springs which have a compression resistance fifty to eighty times greater than the shearing resistance. They will give high resistance to the sideways rocking movement whilst hardly affecting the vertical natural frequency at all.

Types of Spring

The springs under the inertia block may be of steel or rubber. Steel springs can be of the leaf or coil types. The leaf spring will generally introduce a fair amount of damping which may or may not be desirable depending on the circumstances. It has the slight advantage over coil springs that it is naturally more stable laterally. On the other hand coil springs are simpler to install. There is no need to fear fatigue failure of either form of spring since the dynamic deflections are very small compared with the static deflection. Corrosion need not be a problem since protective coatings can be applied, and arrangements can be made to inspect, and if need be replace, spring units during the life of the hammer.

Rubber springs have the advantage that, like coil springs they are extremely simple to install. Indeed, the carpet type of rubber mounting can be the simplest of all, since, if continuous over the whole base, it can simplify the casting of the inertia block above it.

Doubts are often expressed about the life of rubber springs. However, the flexing of the rubber is very small compared with that in the treads of tyres which are also subject to violent abrasion. The flexure is also negligible compared with that in axle box springs and bolster springs which are used on rolling stock. Some springs of this kind have been in use on L.P.T.B. underground trains for twelve years now with no signs of needing to be replaced.

Rubber introduces greater damping than steel and there is a consequent build-up of heat. This build-up is remarkably small, however, when the deformations are of the order of those under inertia blocks. In a typical case of a carpet mounting it is unlikely to exceed about 10 deg. Cent. in an eight-hour shift even if there is no escape of the heat. In fact the heat can escape fairly easily into the ground and into the inertia block, and is also carried away by the air moving around and under the inertia block as it oscillates. If deterioration of the rubber springs is feared it is easy to design the foundation so that the springs can be taken out and replaced, just as with steel springs. Apart from their simplicity, rubber springs, particularly the carpet type, have the advantage that they can be bought "off the shelf" with a wide range of stiffnesses. They are also likely to be cheaper than steel.

For the springs mounted at the side of inertia blocks, where it is necessary to control sideways or rotational movement whilst imposing negligible resistance to vertical movement, rubber multi-leaf springs are ideal.

It must be kept in mind that rubber springs are non-linear, that is, the load deflection graph is not a straight line. In the case of certain springs used by the author the static deflection will generally have to be about 20 per cent greater than that of a linear spring to produce the same dynamic behaviour.

Bad Ground

Where ground conditions are poor it may be necessary to reduce dynamic loads on the ground to very small values indeed to prevent progressive settlement of the hammer. In that case the standard procedure suggested in Conclusion 1 below will need modification. Each case will need special consideration.

Conclusions

The principal conclusions to be drawn from this article may be summarised as follows :

1. Provided the ground is reasonably good about 80 or 90 per cent suppression of ground vibrations will be obtained if an inertia block at least as large as would be used in a conventional foundation is placed on springs which deflect about 0·25in under the static load. If the springs are non-linear an appropriately larger deflection would be needed. The block must be completely surrounded by an air space.

2. With this arrangement there will not normally be any need to use special damping devices as the energy of the oscillations will be damped out by leakage into the ground. There will be no danger of resonance with the so-called natural frequency of the ground.

3. Where even greater insulation is needed a larger inertia block can be used and, if necessary, softer springs which give a greater static deflection. If the latter course is adopted there may be insufficient decay of the vibrations due to leakage of energy into the ground. In those circumstances it may be necessary to install dampers, preferably of a kind which act only on the upward swing.

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[3] Arnold, R. N., Bycroft, G. N., and Warburton, G. B., "Forced Vibrations of a Body on an Infinite Elastic Solid," *Journ. Applied Mech.*, Vol. 77 (1955), page 391.
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Dispersal of Warm Effluent in Coastal Waters

SEA TEMPERATURE STUDIES

By A. W. WYNESS*

IN 1959, for the third successive year, the South Eastern Division at Brighton has co-operated with the Central Electricity Generating Board Station Planning Department in surveying the distribution of the warm cooling water released into the sea. The object of the surveys has been to provide information for the design of power stations, especially nuclear ones, which require very large quantities of cooling water, and are being sited on tidal waters. The information is also needed at Public Inquiries as to proposed coastal power stations, such as at Dungeness. The Dungeness nuclear station will be of 550MWcapacity and will need 35,000,000 gallons of cold water per hour. The effect of this water on the sea temperature is of interest to local residents who may gain their livelihood from the sea.

The most unfavourable circumstances for cooling are slack tide and shallow water with the outfall at surface level. The Brighton surveys have been carried out in these conditions.

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Method of Measurement

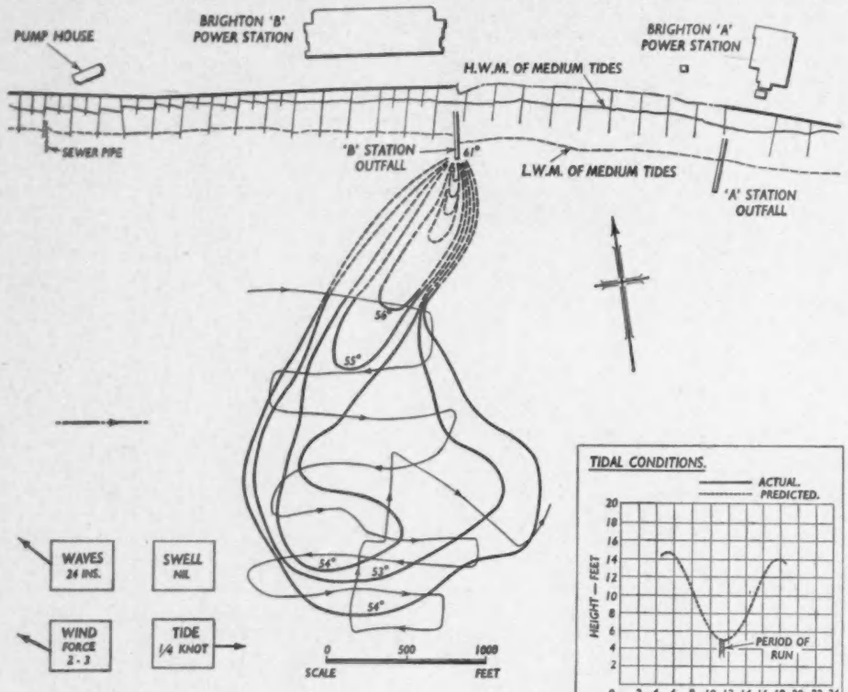
The method is to measure the sea temperature from a boat (Fig. 1) and to plot the isotherms (lines connecting points of equal temperature) on specially prepared charts. Tidal and wind conditions are, of course, not static. To obtain maximum accuracy under continuously changing conditions it is necessary to take temperature readings over the "cooling pond" area as rapidly as possible. The area of sea affected may extend several hundred yards from the shore

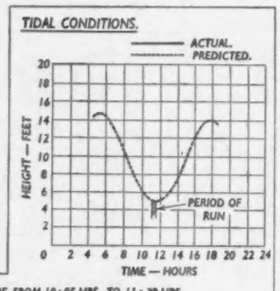
Fig. 1—Arrangement of equipment in boat

and, ideally, several boats would be used. This would be expensive and difficult to organise, so efforts have been concentrated on making the single boat as efficient as possible.

Speeding Up Readings

The Southern Division has made similar surveys in Southampton Water and in the Solent, and its experience and advice has been very valuable. The method was to have a temperature sensitive probe (thermistor) trailing in the water from a boom over the side of the boat and connected to an electrical measuring circuit. Temperature readings were obtained by adjusting the instrument controls and using a conversion scale. This was of necessity slow and the boat speed had to be limited accordingly. For plotting the boat's position, bearings were taken on prominent landmarks, using two sextants, each time a temperature reading was taken. It can be seen that there was a good deal of activity on board. In reviewing this scheme the aim of the Divisional team was to speed up the operation by automatic measurement and recording of temperature. This was done in 1957 by the Technical Department using the same type of thermistor bridge connected to a servo amplifier and chart recorder. The chart recorder is unaffected by movement of the boat, usually a small launch, and in reasonable weather the boat can proceed at a steady pace. Three recorders have been made enabling simultaneous readings to be taken at different depths.





DAY, WED. DATE, 19TH. MONTH, NOVEMBER. YEAR, 1958.

RUN No. 1. DEPTH: SURFACE.

LEGEND.

ISOTHERMS (MEASURED) 55

ISOTHERMS (INFERRED) 55

LAUNCH TRACK.

FLOAT RUN.

SURVEY TIME FROM 10·05 HRS. TO 11·38 HRS.

PHASE. NEAP

METHOD OF MEASURING.
HEIGHT: ADMIRALTY TIDE TABLE
DIRECTION: VANE FLOAT

POSITION	TIME	SPEED FT./MIN.	DIRECTION
S.W. OF OUTFALL	10·28 10·54	10	E

SEA CONDITIONS.

DESCRIPTION	LENGTH FT.	HEIGHT INS.	PERIOD No. PER MIN.
WAVES	READINGS NOT TAKEN HEIGHT VARIABLE UP TO 24 INS.		
SWELL		NIL	

AMBIENT TEMPERATURES

POSITION	TIME	DEPTH FT.	TEMP.
LOWEST RECORDED TEMPERATURE ON RUN.	11·10	6	51·0
ON BEACH.	11·14	SURFACE	51·0

WEATHER CONDITIONS.

BAROMETER. HEIGHT: 30·38 INS. MOVEMENT: STEADY

CLOUD. 6/10

VISIBILITY. GOOD

WIND

POSITION	TIME	SPEED FT./MIN.	DIRECTION
ESTIMATED FROM LAUNCH		1000	S.E.

AIR TEMPERATURE

POSITION	TIME	TEMP. WET	TEMP. DRY	HUMIDITY PER CENT
ON BEACH	11·30	50·5	52·0	90

INSTRUMENTS.

BEACH. MERCURY THERMOMETER

LAUNCH. THERMISTOR AND RECORDER AT SURFACE. 3'-0" & 6'-6"

PLANT.

	STA. 'A'	STA. 'B'
No. OF SETS	NIL	3 x 55·5, 1 x 60 = 226·5 MW
MW GENERATED	NIL	223 MW

C.W.-FLOW

STA.	TIME	FLOW 1,000 GALLS./MIN.	TEMP. INLET	TEMP. OUTLET	TEMP. DIFF.	HEAT REJECTION 1,000,000 B.T.U's./MIN.
'B'	11·00	175	52·0	61·0	9·0	15·75
	11·30	176	52·0	62·0	10·0	17·60

Fig. 2—Survey charts

Improved Plotting

Experience in 1957 showed that the sextant method of plotting, though satisfactory in sheltered waters, had serious disadvantages in the open sea. The movement of the boat in a choppy sea made accurate sighting all but impossible and very hard work for the user who could scarcely keep his balance. It was resolved that the taking of bearings must be improved, and last year theodolite bearings were taken from two points on shore. These bearings were plotted and positions passed to the skipper by v.h.f. radio telephone. The scheme worked well, plotting is of a higher accuracy in all weather conditions and is carried out in comfort. Divisional trainees instructed in the use of the theodolites quickly became proficient.

Results

The results of the survey are compiled in the form of a report and twenty charts. Fig. 2 shows such a chart with typical isotherms. The water gives up 90 per cent of its heat by mixing with the surrounding sea and the rest by cooling to atmosphere. It tends to remain at the surface and is carried away by the tidal stream. At Dungeness the outfall will be close to a promontory which should carry the water well clear of the land. Cooling down to 5 deg. above ambient is very quick and then slower down to +1 deg. which is the limit of the survey. This temperature change may be detected for 2 or 3 miles under some conditions.

The 1959 survey has covered the same ground as in previous years, but with 300MW output from Brighton "B" as against 100MW in 1957 and 200MW in 1958. It is hoped that the results will help to programme a computer study of the behaviour of larger cooling systems. Thus the Brighton surveys will have had more than a local significance.

Acknowledgments

Acknowledgment is due to the chief planning engineer and to the divisional controller, South Eastern Division, Central Electricity Generating Board, for permission to publish this article and to the chief planning engineer for permission to reproduce Fig. 2.

The Fairlie Locomotive

ITS USE THROUGHOUT THE WORLD

By R. A. S. ABBOTT, Member, Newcomen Society

No. I

The history of the Fairlie locomotive, although of great technical interest, is a subject that has never received due attention from engineering historians, and the literature relating to this particular phase of locomotive development is extremely limited and is mainly confined to isolated references in early periodicals. When the history of the seventeen Fairlie locomotives that have operated on railways in Great Britain and Ireland was published in "The Engineer" for December 5, 1958, the author expressed the hope that at some future date he would be able to deal with the use of this type of locomotive in other parts of the world. Now, as much hitherto unpublished information has recently been released from official sources both in Great Britain and overseas, it has become possible to present for the first time a more comprehensive survey of the world use of the Fairlie locomotive.

ALTHOUGH a number of Fairlie locomotives described here were previously unknown and many classes have never before been illustrated in any publication, the author is not so sanguine as to believe that the record is complete. This double-boiler double-bogie locomotive was a design from which, in the early 1870s, a great performance was expected, and after the famous trials on the narrow-gauge Festiniog Railway with the "Little Wonder" in 1870, the Fairlie principle was widely acclaimed and a big demand for these locomotives was anticipated for overseas railways. On steeply graded railways with sharp curves the type achieved a certain degree of success, and a large number of these locomotives continued to give satisfactory service for many years. But quite a number of early Fairlies often failed to survive their first magnified prestige, probably due to poor maintenance facilities and the recurring troubles with the original designs of articulated steam pipes, and so were withdrawn from service after only a few years' work.

The two more successful applications of the Fairlie principle were undoubtedly on the Transcaucasian railway system, where forty-five such locomotives were used, chiefly on the Souram inclines; and on the Mexican Railway on the main line of which, between Cordova and Bocca del Monte (108 miles) no other form of steam locomotive was used over a period of fifty-three years, until the Arizoba–Esperanza section of the line was electrified in 1924.

Robert Francis Fairlie was born in Scotland in 1831 and received his training as a locomotive engineer at Crewe and Swindon. In 1853 he held the position of Engineer and General Manager to the Londonderry and Coleraine Railway. By the early 1860s he was established as a railway consultant with offices at 56, Gracechurch Street, London, E.C., and was concerned with the building of railways in South America and India. The patent for "Improvements in Locomotive Engines and Boilers" was granted on May 12, 1864 (No. 1210), and the general arrangement drawing has already appeared in THE ENGINEER, in the issue for December 5, 1958, page 878.

JAMES CROSS AND CO.

In a little over a year from the granting of the patent the construction of the first double-boiler locomotive, with two power-bogies, was undertaken by Messrs. James Cross and Co., Sutton Engine Works, St. Helens, and this historic locomotive, the "Progress," for the Neath and Brecon Railway, appeared in December, 1865. In 1866, three 0–6–6–0 locomotives were built by Cross and Co. (Works Nos. 28–30) for the Southern and Western Railway of Queensland, Australia. These locomotives (Fig. 1) were built to the designs of Mr. Charles Douglas Fox, C.E., and had cylinders 11in diameter by 18in stroke; wheels 3ft diameter; bogie wheelbase 6ft 6in; distance between bogie centres 16ft; total wheelbase 22ft 6in. The rail gauge was 3ft 6in. The main bearing springs were of the transverse kind, and placed one below each axle.

As springs so arranged have no lateral stability, each bogie was provided, in addition, with four volute springs—a pair near each end—these being placed between brackets fixed to the inside of the main frames and brackets on the boiler. The transverse distance between these springs was only 2ft 1in, and it is doubtful whether they proved very effective. The boiler barrels had a length of 9ft 10in and a diameter of 3ft, each containing 133 tubes 1¾in in diameter. The tube heating surface amounted to 1037·4 square feet, and that of the firebox 72·1 square feet making a total heating surface of 1109·5 square feet. The grate area was 17·4 square feet. The central dome contained a regulator of the gridiron type, and from it the steam passed into a pipe formed by riveting a bent plate along the inside of the boiler top. From this "pipe" the steam entered two small steam chests placed one on each barrel, and from these it was conducted by branch pipes to other chambers, fixed one on the bottom of each barrel, these chambers being annular and forming the sockets into which the bogie pins fitted. From each annular chamber a forked pipe led to the cylinders, this pipe being connected to the chamber by a stuffing-box which allowed the pipe to follow the movements of the bogie. The blast-pipes were also arranged so that they could follow the movements of the bogies and at the same time deliver their jets in the centre of the chimneys. The eccentrics were placed in a very inconvenient position, outside the frames but behind the driving wheel bosses; the valve gear being of the shifting link pattern, with communication to each slide valve through a rocking shaft.

The feed water was carried partly in tanks fixed between the frames under the boiler barrels, and partly in side tanks situated underneath the footplate on each side of the firebox casing, and on the footplate on each side at the bottom of the coal boxes. The combined contents of all these tanks amounted to 1030 gallons. The four coal boxes had a capacity of 120 cubic feet. The total weight of these engines was 30 tons. These three locomotives were built to handle loads of 90 tons up a gradient of 1 in 45 which extended for a distance of 12 miles, and with curves of 330ft radius, but they were never a success and their very poor performance did much to retard the acceptance of the Fairlie locomotive as a practical machine.

Other locomotives supplied by Cross and Co. during 1866 were several of the 0–4–4–0 type to the metre gauge Venezuelan Central Railway, and one, the "Mountaineer," to the Anglesey Central Railway.

FAIRLIE ENGINE AND STEAM CARRIAGE COMPANY

In September, 1869, Robert Fairlie, in conjunction with George England (Junior) and J. S. Fraser (of the Great Western Railway) acquired the Hatcham Ironworks of George England and Co. at New Cross, London, and, under the title of The Fairlie Engine and Steam Carriage Company, proceeded to specialise in the construction of the patent double-boiler locomotive. The first to be completed in 1869 was the well-known "Little Wonder" for the 1ft 11½in gauge Festiniog Railway, followed in the same year by one of the 0–4–4–0 type for the Nassjö-Oscarshamn Railway in Sweden. This locomotive was at first used by the British contractor, J. Morton and Sons, and was named "Morton." After the failure of this firm it was transferred to his successor, Clark, Punchard and Co., who renamed it "Clark." Later it carried the Railway No. 1 and when taken over by N. O. J. in 1874 it was again renamed "Hultenheim." The cylinders were 10in diameter by 18in stroke; wheels 3ft 6in diameter; bogie wheelbase 5ft; total wheelbase 19ft 6in. Boiler barrels 8ft 6in long by 2ft 10in diameter. Heating surface of tubes 763 square feet, firebox 70 square feet, making a total heating surface of 833 square feet. Grate area 11 square feet. Capacity of water tanks 700 gallons, while the coal bunkers held 15 cwt. Total weight 25 tons. This locomotive ceased work in 1902 after a boiler explosion.

From a contemporary report in the technical press, it would appear that two such locomotives had been built in 1869, to the order of the Nassjö-Oscarshamn Railway, and both were tested on the Hatcham "circle." However, it is now known that the second one was in use on the Chemins de fer de la Vendée in France by 1871. When this line was taken over by the State system in 1879 this locomotive was already out of use.

In 1870 a 0–6–6–0 locomotive, the "Tarapaca" (Fig. 3) was completed for the Iquique Railway, in Peru (due to territorial changes in this area the city of Iquique is now in Chile), a line owned at that time by Messrs. Montero Brothers. Intended for a duty that involved the hauling of 150 tons up an incline of 1 in 26 for a distance of 11 miles, this locomotive had cylinders 15in diameter by 20in stroke; wheels 3ft 6in diameter; wheelbase of bogies 7ft 8in; distance between centres of bogie pins 20ft 3in; total wheelbase 27ft 11in. Length of boiler barrels 10ft 6in by 3ft 10in diameter. The heating surface of the tubes amounted to 1500 square feet and that of the two internal fireboxes to 125 square feet, giving a total heating surface of 1625 square feet. The grate area was 21 square feet. The large water tanks held 2200 gallons. The valve gear was Allen's straight link motion, and the eccentric rods were cranked to pass above and below the central axle of each bogie. The boiler was carried by

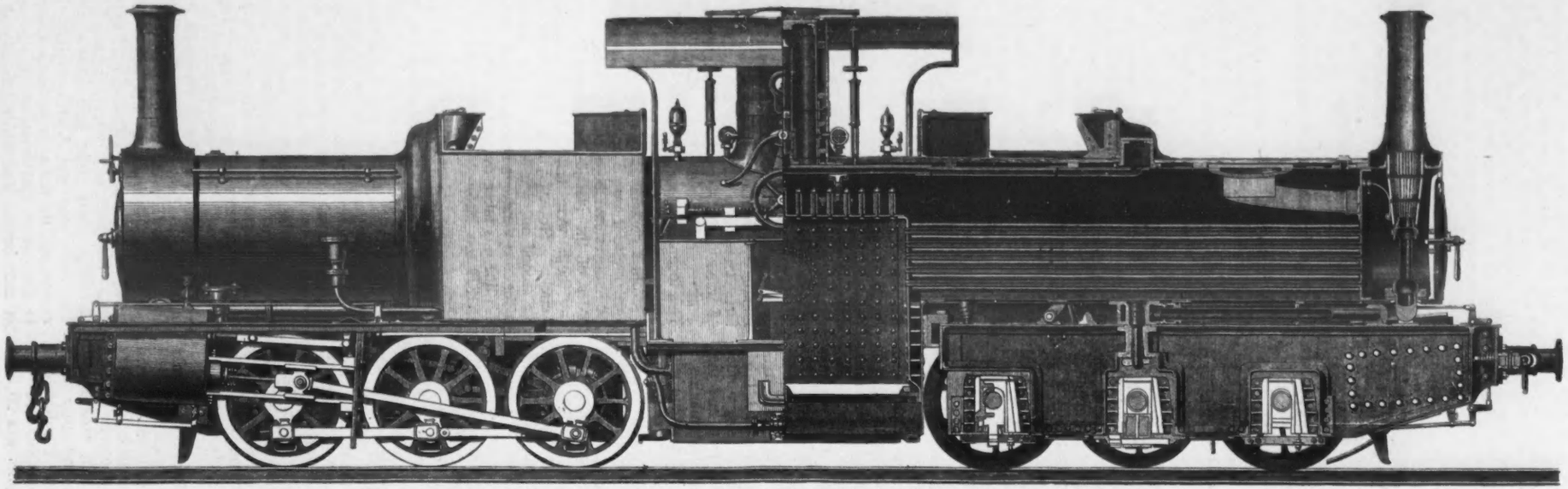


Fig. 1—Locomotive by James Cross and Co., St. Helens. Built 1866 for the Southern and Western Railway of Queensland

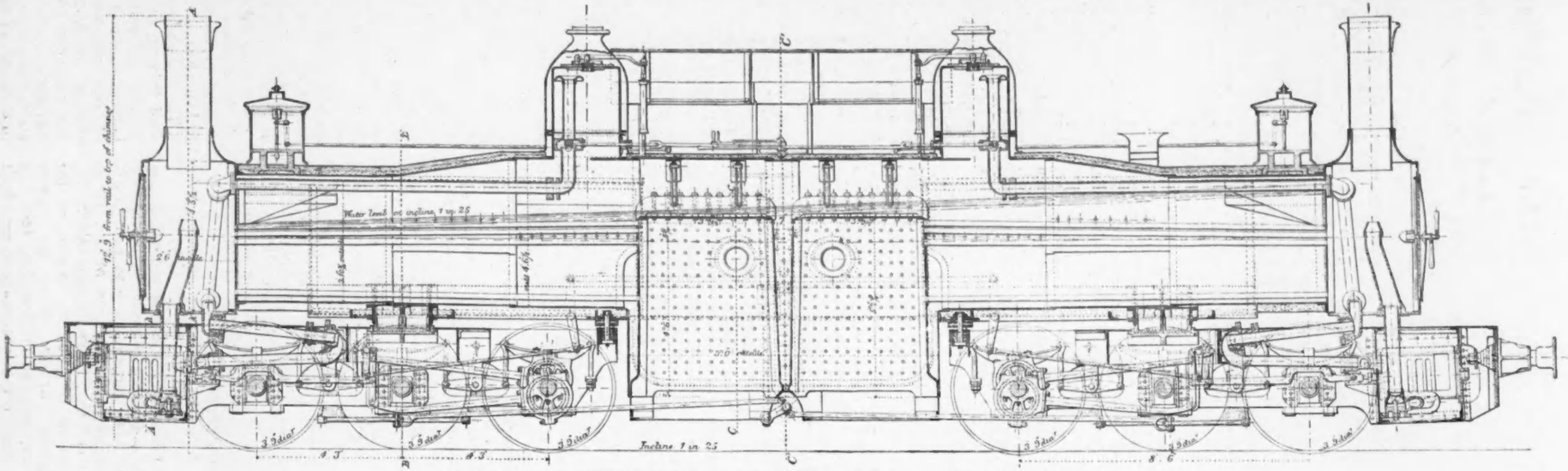


Fig. 2—Locomotive built in 1873 for the Iquique Railway, Peru, by the Avonside Engine Company

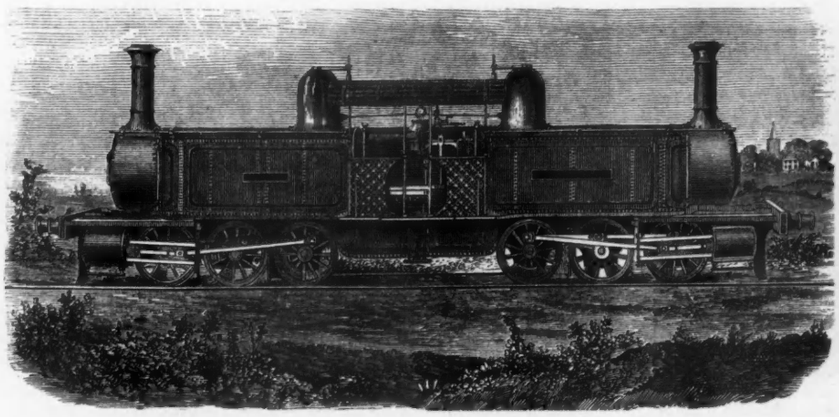


Fig. 3—The "Tarapaca," built by the Fairlie Engine and Steam Carriage Company, London, in 1870 for the Iquique Railway, Peru

transverse bearers of suitable form which extended under each barrel near the middle of its length and connected the pair of "carrier" frames, which passed along the sides of the firebox casing at a higher level than the bogie frames. These carrier frames served to connect the two bogie pins and to transmit any pull or thrust from one bogie to the other, so relieving the boiler barrels of all traction stresses. The bogie pivots each had a flat bearing surface 1ft 8in diameter with a hole 6¼in diameter in the centre. The bogie pin, of gunmetal, passed through this hole and was made hollow in order to conduct steam to an annular chamber from which a steam pipe led to the cylinders. At the rear of each bogie next the firebox, the frames were connected by a cast iron transverse stay, the upper flange of which had a slot curved to an arc struck from the centre of the bogie pin. Through this slot passed a pin which served to connect the bogie frame with a plate iron bracket on the underside of the boiler, there being placed on this pin a number of india rubber rings which served to steady the bogie frame and check any tendency to "kick" when the engine was pulling hard. This arrangement was covered by the original patent specification, and with various modifications was used on all future locomotives.

When the "Tarapaca" was tried on the "circle" at Hatcham Works it traversed the curves of 50ft radius with ease; these curves were, of course, quite exceptional and on the railway for which it had been built the sharpest curves had a radius of 800ft. With a weight of 60 tons this engine was, at the time of its construction, one of the most powerful locomotives in the world. Also in 1870 a 0-4-4-0 locomotive was built for a railway in New South Wales, but was purchased new by the Burry Port and Gwendraeth Valley Railway in Carmarthenshire. The principal dimensions were identical with those of the Swedish and French engines of 1869.

The Hatcham Ironworks does not seem to have prospered under the new management for the above five locomotives appear to have been the total output up to the time that the business was closed down and the machinery sold by auction on May 14, 1872. However, under the title of the Fairlie Engine and Rolling Stock Company, offices were taken at Palace Chambers, Victoria Street, Westminster, and locomotives continued to be designed as late as 1878 for construction by outside firms. The extreme flexibility of the Fairlie type would seem to render it unsuitable for prolonged high speeds, yet in spite of this several designs were certainly prepared for locomotives for express passenger service. One such specification was for a 0-4-4-0 with 5ft 9in wheels and with cylinders attached to framing of the "Crewe" or Allen-Buddicum pattern. This design is illustrated in *The Locomotive* for 1925, page 107, and is thought to have been intended for a French railway.

An article by Robert Fairlie, with the title of "Die Alpenlokomotive der Zukunft" was published in *Technische Mitteilungen* at Zurich during 1876, and from this it is apparent that by March of that year his patent locomotive was in use on forty-three railways.

In the course of a professional journey to Venezuela in 1873, Robert Fairlie contracted blood poisoning and sunstroke, a misfortune from which he never fully recovered although he continued to take an interest in his business affairs until the day before his death which occurred on July 31, 1885.

From 1870 several of the old-established locomotive building firms took up the manufacture of the Fairlie type, and in view of this it will be convenient to deal with the productions from each builder in chronological order.

Sharp, Stewart and Co., Atlas Works, Manchester

During February, 1871, an Imperial Russian Commission paid a visit of inspection to the celebrated Festiniog Railway and there witnessed some interesting trials with the locomotive "Little Wonder," and as a result of this a recommendation was made by the commission for the building of a system of narrow-gauge lines in Russia. In May, 1870, construction had commenced on the Imperial Linvy Railway, the gauge adopted being 3ft 6in, and the line, which was a little over 38 miles long, was completed in April, 1871. To work the new line, an order for five 0-6-6-0 locomotives was placed with Sharp, Stewart and Co. (Works Nos. 2088–92) and these were all delivered in 1870.

These locomotives (Fig. 4) had cylinders 13in diameter by 18in stroke; wheels 3ft 3in diameter; bogie wheelbase 7ft 6in; bogie centres 20ft; total wheelbase 27ft 6in. The boiler barrels were 10ft 6in long by 3ft 3½in diameter, having a tube heating surface of 1210 square feet, which, together with 115 square feet provided by the two internal fireboxes, gave a total heating surface of 1325 square feet. The grate area was 21 square feet. The boiler pressure was 140 lb per square inch and the estimated tractive effort was 15,600 lb. The water tanks held 1250 gallons, and the fuel racks could accommodate 200 cubic feet of wood, while the total weight of the locomotive in working order was 46 tons.

One detail in which these Linvy engines differed from those previously built was in the arrangement of the centre pins of the bogies. The frames of each bogie were braced together by transverse and diagonal stays near the middle of their length, and these transverse stays supported a cast-steel socket in which the brass centre pins rested. As in all later Fairlie engines the boiler was supported by carrier frames, to which the bogie pins were fixed. These centre pins were 12in diameter and made with flat ends, but the whole weight of the boiler did not rest on these pins however, each of the latter being supplemented by two segmental blocks which rested on a plate carried by the above-mentioned transverse stays.

These locomotives were followed in 1871 by ten of the 0-6-6-0 type for the Tamboff and Saratoff Railway (Fig. 5). Built to the Russian gauge of 5ft these engines (Works Nos. 2118–2127) had cylinders 15in diameter by 20in stroke; wheels 3ft 6in diameter; bogie wheelbase 8ft; total wheelbase 29ft 3in. The boiler barrels had a length of 11ft 3in, and a diameter of 2ft 9¾in, the combined tube heating surface being 1500 square feet. With 125 square feet contributed by the two fireboxes the total heating surface was 1625 square feet. The grate area was 21·3 square feet. The capacity of the tanks was 1800 gallons, and that of the bunkers 300 cubic feet of wood. The weight empty was 45 tons 18 cwt. The Tamboff and Saratoff Railway later formed part of the Transcaucasian system, and the above locomotives were all converted to oil burners, the large fuel tanks being mounted on top of the boiler barrels.

In 1870 two 0-4-4-0 locomotives were delivered to the Nassjö-Oskarshamn Railway,

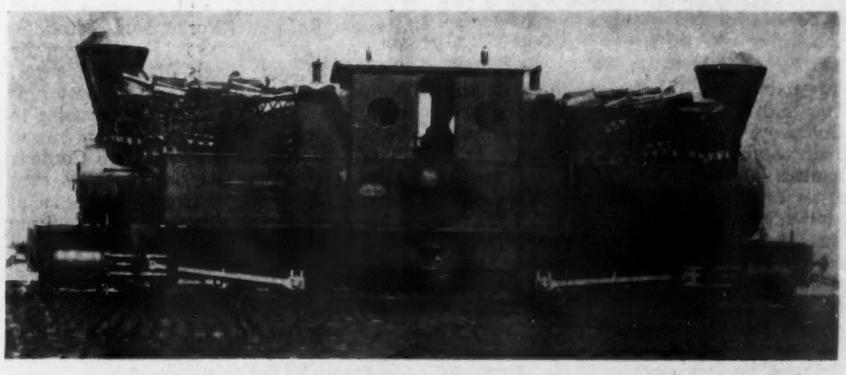


Fig. 4—Locomotive built by Sharp, Stewart and Co., in 1871 for the Imperial Linvy Railway, Russia

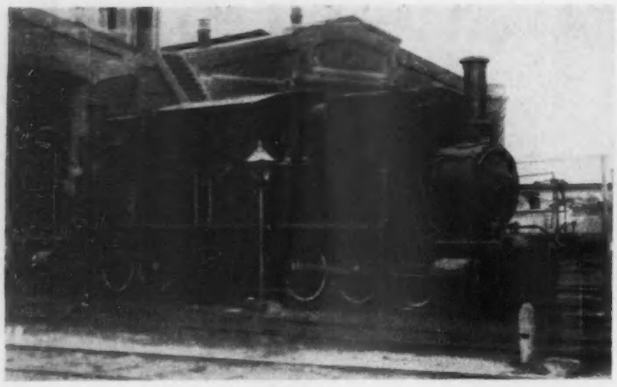


Fig. 5—Locomotive on the Transcaucasian railway system, originally built in 1871 by Sharp, Stewart and Co. for the Tamboff and Saratoff Railway

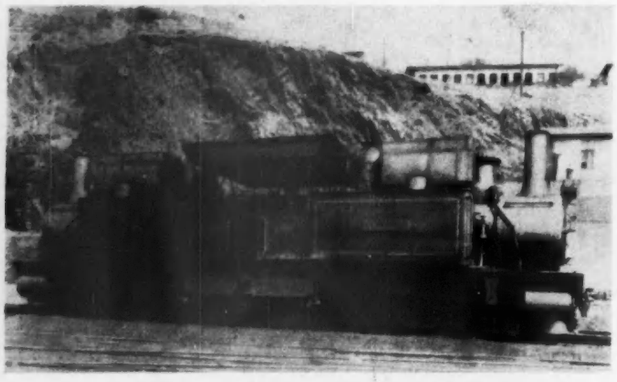


Fig. 6—Locomotive by the Avonside Engine Company for the Nitrate Railways, Chile, in 1872

Sweden (Works Nos. 2190–1), followed during 1871 by two more (Works Nos. 2239–40). These four engines had cylinders 10in diameter by 18in stroke ; wheels 3ft 6in ; tube heating surface 763 square feet, firebox 70 square feet ; total 833 square feet. The coal bunkers held 50 cubic feet and the capacity of the water tanks was 900 gallons. This class was very similar to the " Morton " and their railway numbers, names and subsequent history were as follows:

2. " Eskjö " : reboilered 1897 : scrapped 1911.
3. " Nassjö " : reboilered 1894 ; scrapped 1911.
4. " Oskarshamn " : reboilered 1896 ; scrapped 1910.
5. " Hultsfred " : sold 1899 to contractor.

Two Fairlie locomotives were ordered by the Great Russian Railway (Grande Societe of the St. Petersburg and Moscow Railway) from Sharp, Stewart and Co. during 1870 and it is thought that these were the unique and little known 2–4–4–2 type with inside cylinders and 5ft 6in diameter coupled wheels, that appeared on the above railway during 1871–72.

Avonside Engine Company, Bristol

The Avonside Engine Company took up the manufacture of the Fairlie locomotive in 1871, and between that year and 1881 produced more of this type than any other British builder. It is, therefore, all the more

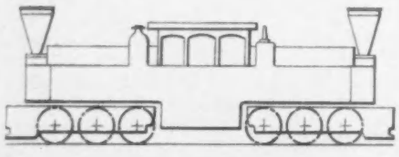


Fig. 7—Diagram of the " Caledon," built in 1871 by the Avonside Engine Company for the Toronto, Grey and Bruce Railway, Canada

regrettable that the records of this firm, now in the possession of the Hunslet Engine Company, Ltd., Leeds, are very incomplete and no official photographs of Fairlie locomotives are available, while the general arrangement drawings of only six designs now survive. It should be noted that it was the custom to allocate two works numbers to each double-boiler locomotive, although this was not always strictly adhered to in practice.

The earliest locomotives appear to have been two 0–6–6–0 sent to Peru during 1871, followed by two more in 1872. These are thought to have gone to the Pisagua Railway and had cylinders 15in diameter by 20in stroke ; wheels 3ft 6in ; a total heating surface of 1685 square feet and a water capacity of 2200 gallons. The 3ft 6in gauge Toronto, Grey and Bruce Railway in Canada ordered one 0–6–6–0 in 1871, and this locomotive, the " Caledon " is illustrated here in Fig. 7. The cylinders were 11½in diameter by 18in stroke ; wheels 3ft 3in diameter ; bogie wheelbase 7ft 6in ; total wheelbase 26ft 3in. The boiler barrels had a length of 10ft, and were 3ft 0⅜in in diameter ; the tube heating surface being 858 square feet. The heating surface of the two fireboxes was 103 square feet, and the grate area amounted to 20 square feet. The water tanks held 1400 gallons, and 200 cubic feet of wood could be carried. This locomotive was scrapped in 1881 when the T.G. & B. Railway was made a standard gauge line under Canadian Pacific control. An identical locomotive was also supplied in 1871 to the Toronto and Nipissing Railway another 3ft 6in gauge line.

The Poti and Tiflis Railway in Georgia was commenced in 1869 from Poti, a small port on the Black Sea and completed to Tiflis, a distance of 196 miles, in October, 1872. Near the summit of the Souram Pass the gradient is 1 in 22½ and to work this difficult section four 0–6–6–0 locomotives were built in 1871 (Works Nos. 872–879), followed in 1875 by five more (Works Nos. 1115–1124). These engines had cylinders 15in diameter by 22in stroke ; wheels 3ft 7in diameter ; total heating surface 1685 square feet, a water capacity of 2200 gallons, and were originally wood burners. It was customary to use three of these 60-ton locomotives on passenger trains over the Pass.

This railway was later incorporated into the Tanscaucasian railway system, and the above nine engines were eventually converted to oil-firing. During 1871 three 0–6–6–0 locomotives were delivered to the Mexican Railway (Works Nos. 880–885), and these had cylinders 15in diameter by 22in stroke and wheels 3ft 7in diameter. The main line of the Mexican Railway runs from Vera Cruz to Mexico City, passing to the south of the Orizaba mountain range. There is a continuous ascent from Cordova (altitude 2713ft). The rise continues even more steeply up to the summit of the line at Bocca del Monte (altitude 7923ft). From this point the line runs along an elevated plateau to Mexico City (altitude 7350ft). These Fairlie locomotives were used on the section from Cordova to Bocca del Monte (108 miles), and were the first of no less than fifty delivered to the line during the next forty years by five British builders.

Another Canadian line to use the Fairlie type was the Glasgow and Cape Breton Railway, a 3ft gauge line in Nova Scotia. Three of the 0–4–4–0 type were sent out in 1871 (Works Nos. 907–912) and these locomotives (Fig. 8) had cylinders 11in diameter

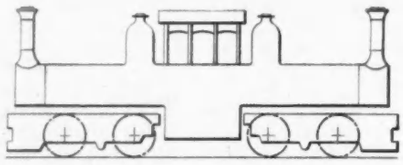


Fig. 8—Diagram of locomotive for the Glasgow and Cape Breton Railway, Nova Scotia, built by the Avonside Engine Company in 1871

by 19in stroke ; wheels 3ft 3in diameter ; bogie wheelbase 5ft 6in ; total wheelbase 21ft 4in. Length of boiler barrels 9ft 6in ; diameter 3ft 0¼in. Total heating surface 922 square feet. Grate area 13·25 square feet. Capacity of water tanks 1000 gallons. The coal bunkers held 1 ton 3 cwt.

Eight 0–6–6–0 locomotives (Fig. 6) were built in 1872 for the Nitrate Railways in Chile, a line connecting the ports of Iquique and Pisagua with the nitrate area and rising to an altitude of 3811ft. These locomotives (Works Nos. 886–893) carried railway numbers 9 to 16, and had cylinders 15in diameter by 22in stroke ; wheels 3ft 7½in diameter ; bogie wheelbase 8ft ; total wheelbase 29ft 1in. Total heating surface 1607 square feet. Grate area 24 square feet. Working pressure 140 lb per square inch. Total weight 81 tons. Nos. 9, 10 and 15 were still in service in 1932. Six more were supplied during 1874 (Works Nos. 944–949) and one in 1880, and these received railway Nos. 17 to 22 and 32 respectively. These locomotives were generally similar to those of 1872, but had cylinders 15½in diameter by 20in stroke and Walschaerts valve gear. Two of this series, Nos. 18 and 19 remained in traffic in 1932.

The Iquique Railway in Peru ordered five 0–6–6–0 locomotives from the Bristol works in 1873 (Works Nos. 1024–1028) and these are illustrated in the general arrangement drawing (Fig. 2). The cylinders were 16in diameter by 20in stroke ; wheels 3ft 9in diameter ; bogie wheelbase 8ft 6in ; distance between bogie pins 22ft ; total wheelbase 30ft 6in. The heating surface of the tubes was 1650 square feet and that of the fireboxes 166 square feet, giving a total of 1816 square feet. The grate area was 28 square feet. With 2100 gallons of water and 2 tons of coal the weight was about 56 tons. In these particular engines the main frame had heavy cross stays at each end carrying a

flat-faced brass casting or pin, about 19in in diameter, which rested upon a cast iron socket fixed to strong cross stays at the centre of each bogie frame. The broad bearing surface of this pin in itself gave considerable lateral stability, but additional security was given by blocks of wood fitted to brass slides, and arranged at the sides between the bogie frames and the cross stays of the main frame.

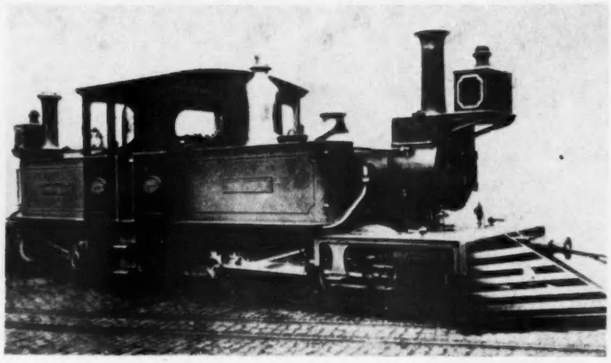


Fig. 9—The "Santa Lucia" built 1874 by the Avonside Engine Company for the Northern Railway of Montevideo, Uruguay

Next in date order were three 0–6–6–0 locomotives for the 3ft gauge, and with cylinders 13¾in in diameter by 18in stroke, recorded in the official register as having been sent to Spain in 1873 (Works Nos. 958–963) ; one of these carried the name of "Escaldor del Montes." On page 11 of *Narrow Gauge Railways in America* by G. Hardy and P. Darrell, 1949, there is an illustration of the "Escaldor del Montes," and it is there stated to have been built for the Venezuelan Government. In view of this it seems reasonable to suppose that all three locomotives went to South America, and were perhaps exported through an agent in Spain.

A further order was executed for the Mexican Railway in 1874 and one of these locomotives (Works Nos. 950–957) is illustrated in Fig. 10. They were larger than the original series of 1871 and had cylinders 16in diameter by 22in stroke ; wheels 3ft 9in in diameter ; bogie wheelbase 8ft 3in ; total wheelbase 30ft 3in. The boiler barrels had a length of 11ft 4in and a diameter of 3ft 10¾in at the front ring. The total heating surface was 1816 square feet and the grate area 28 square feet. Capacity of water tanks 2100 gallons. These engines were wood burners, and carried railway Nos. 28–31.

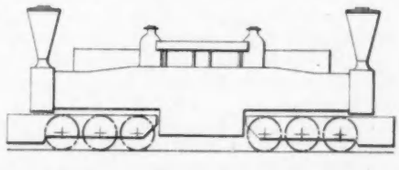


Fig. 10—Diagram of locomotive for the Mexican Railway built by the Avonside Engine Company in 1874

In 1874 two 0–4–4–0 locomotives were built for the 3ft 6in gauge lines in New Zealand, one, "Lady Mordaunt" (Works Nos. 1044–5) for the Otago Provincial Council to the order of the Fairlie Engine and Rolling Stock Company, and the other, the "Snake" (Works Nos. 1022–3) for the General Government. The engines were the first in New Zealand to have the Walschaerts valve gear, and had cylinders 9in diameter by 16in stroke ; wheels 3ft 3in in diameter ; bogie wheelbase 4ft 6in ; total wheelbase 19ft 6in. The total heating surface was 766 square feet with a grate area of 12½ square feet. The water tanks held 700 gallons, and 70 cubic feet of peat could be carried in the bunkers. The weight was 23 tons. The "Lady Mordaunt" was scrapped in 1896, and "Snake" was withdrawn from service in 1884 and dismantled in 1890. A photograph of "Snake" was published in THE ENGINEER for January 30, 1959, page 180.

The Northern Railway of Montevideo, in Uruguay, was a local railway which ran from the city of Montevideo to the village of Santa Lucia. The principal traffic consisted of meat from the abattoirs at the latter place, established there in connection with the cattle industry. This railway possessed two 0–6–6–0 locomotives named "Montevideo" and "Santa Lucia" (Fig. 9). Although the date of building is recorded in the register as 1874, the complete set of original working drawings, which are still preserved at the Peñarol Works of the State Railways, are all dated between January and April, 1878. The cylinders were 11in in diameter by 16in stroke and one unusual feature for a British-built locomotive was the use of Stephenson valve gear with outside eccentrics. The very rare photograph reproduced here was recently discovered at the home of an ex-railwayman, eighty years of age, in Montevideo. One of these locomotives was reported to be out of use in 1908.

A further series of six 0–4–4–0 locomotives were built in 1875 for New Zealand (Works Nos. 1060–1071) and intended for service in Otago, but later they were used for construction work on the North Island Main Trunk Railway. The cylinders were 11in in diameter by 18in stroke, with Walschaerts valve gear ; wheels 3ft 3in in diameter and a weight of from 34 to 37 tons. As built they had balloon stacks with a sandbox at the base ; later they were given extended smokeboxes and handsome flanged chimneys. Numbered 172–174 and 176–178, this class was particularly unfortunate and gave constant trouble with the flexible steam pipes, and they also had a habit of fracturing their frames when working on the severely curved Wanganui section. Scrapping of these engines began in 1898, but the last one, No. 174, survived out of use at New Plymouth Sheds as late as 1920. This class was illustrated in THE ENGINEER for January 30, 1959, page 180, and a photograph of the engines as originally built appeared in *The Locomotive* in 1920, page 205.

(*To be continued*)

Beryllium Fabrication for Reactor Fuel Canning

BERYLLIUM has been chosen as the main canning material for the Advanced Gas Cooled Reactor (A.G.R.) which is being built by the United Kingdom Atomic Energy Authority at Windscale. It is the first commercial application of fabricated beryllium in Great Britain.

Apart from its prospects as a fuel canning and structural material in nuclear reactors, beryllium has promising potential applications in the development of hypersonic aircraft and rockets. It has many properties which make it a serious competitor with titanium in this field ; for example it is lighter, has better heat conductivity and considerably higher rigidity. However, the ductility of beryllium varies with its metallurgical condition and in certain circumstances it exhibits little or no ductility.

To study these and other aspects of beryllium's behaviour an intensive research programme was started by metallurgists of the Atomic Weapons Research Establishment (A.W.R.E.) in 1953. Since then considerable progress has been made in understanding the anomalous ductility values and conventional technological methods have been developed for fabricating the metal under conditions to yield the optimum metallurgical properties.

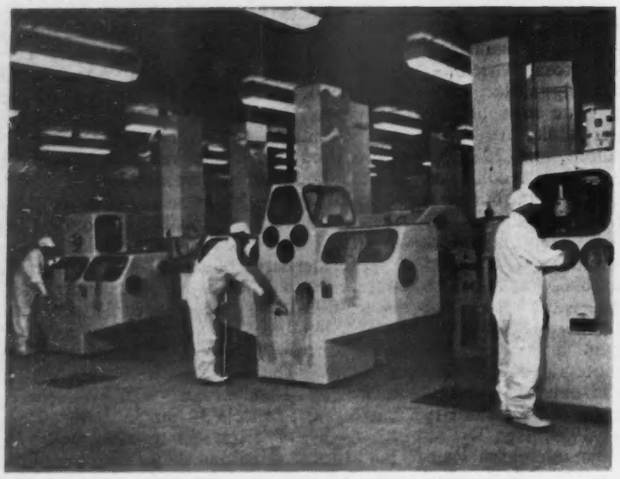
Casting and powder metallurgy systems have been devised together with extrusion and rolling processes as methods for fabricating rod, tube and sheet. Various methods for joining have been successfully developed ; they include electron beam welding, argon arc welding and flame brazing.

A.W.R.E. metallurgists have found that mechanical properties and, in particular, ductility at all temperatures, are markedly affected by the small amount of impurities present even in purified metal ; commercial purity metal is very sensitive to the condition in which the impurities are distributed. Further the brittle nature of the metal at 20 deg. Cent., has been found to be associated with a brittle-ductile transition at 185 deg. Cent., a property usually found in other metals at much lower temperatures. At a higher temperature, 1250 deg. Cent., the metal changes its crystal structure. This change was first observed at A.W.R.E., and attempts are being made to exploit it with a view to further improving mechanical properties.

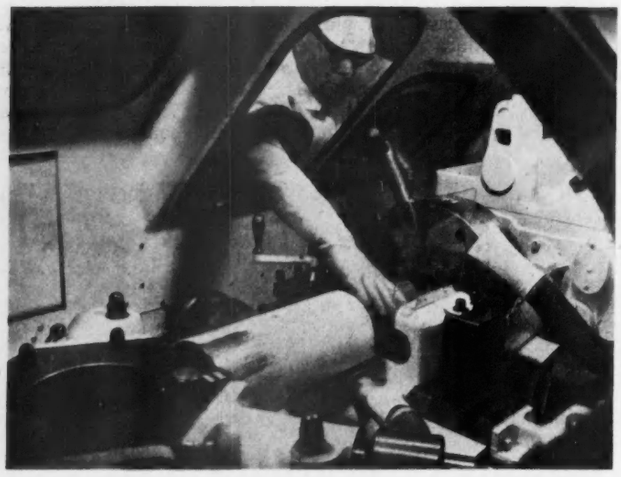
Fuel Element Canning

A more specific aim—the production of fuel elements capable of retaining their integrity over an economic life span—motivates the work that is being done on beryllium in the Development Group and the Engineering and Production Group of the U.K.A.E.A., and at the Authority's Research Establishment at Harwell.

Two major tasks which faced the Authority at the start of the work were first an assessment of the merits and demerits of the alternative sources of raw material and fabrication routes and, secondly, the development of selected routes to the point where material specifications were available for the control of the bulk production of components by industry. The assessment of the metal has required both out-of-pile tests and tests at the anticipated levels of irradiation in A.G.R.



Beryllium machining plant with machines totally enclosed in ventilated glove boxes



Lathe enclosed in glove box equipped with high-air-velocity extraction system to remove beryllium particles

The effort has therefore been devoted to a variety of problems, both practical and theoretical, including the following :

1. The assessment of various production, fabrication and welding techniques.
2. The development and assessment of new methods of fabrication including arc melting, electron beam melting and new sintering methods.
3. The further development of specific processes such as the extrusion of fine bore tubing to close dimensional tolerances.
4. The theoretical and practical evaluation of the effects of irradiation on the physical, chemical, mechanical and metallurgical characteristics of the metal.
5. Studies of the effect of impurity elements on the properties coupled with the development of new production techniques aimed at the production of ultra-pure metal.
6. Theoretical and practical studies of the mechanism of deformation of the metal and of the structure, particularly the preferred orientation of the deformed metal. This has necessarily included heat treatment studies, aimed at improving understanding of the brittle nature of the metal and, ultimately, at increasing the creep ductility.

Four British firms are now actively engaged in the production and fabrication of beryllium on an industrial scale. They are Imperial Chemical Industries, Ltd. (Metals Division), Witton, Birmingham ; Sir W. G. Armstrong Whitworth Aircraft, Ltd., Baginton, near Coventry, Warwicks ; Tube Investments, Ltd., Chesterfield, Yorks ; and The National Smelting Company, Ltd., Avonmouth, Glos. The last named extracts beryllium from its ores. The other three firms are concerned with various machining and fabrication processes.

The activities of I.C.I., Ltd., in this field were described in an article "Production of 'New Metals'" in our issue of December 18, page 819. It will be recalled that the plant at Witton uses imported flake and pebble beryllium for its raw materials and is designed to work as a research production unit with an output, initially of 7 tons a year. It is contained in a single-storey building divided into contact areas (where beryllium is handled) and non-contact areas (which are free from beryllium). All the contact areas, including production zone, laboratories, and ventilation bay are designed to simplify dust control. There are no windows and the incoming air, filtered and heated, is changed every three minutes and extracted through machine enclosures, glove boxes and special ducts. About 200 tons of air are moved every hour and passed through absolute filters before being discharged from a 150ft chimney. A negative pressure created inside the building by the ventilation system ensures that all contact air follows a designated route through the exhaust filters, keeping adjacent areas uncontaminated.

To produce metal with superior mechanical properties, particularly in regard to ductility, powder metallurgy techniques are employed. The cast ingot is machined to swarf, which in turn is ground to fine powder. This powder is then packed into graphite moulds and sintered at high temperature under vacuum. Solid compacts produced in this way are either machined to finished size or prepared for further processing. Rod and tube are produced by extrusion during which seizing in the dies is avoided by plating the extrusion slug or enclosing it in a protective mild steel sheath.

Careful design of equipment handling powdered beryllium ensures that air contamination is kept within the prescribed limit. Suction pipes working with a velocity of 10,000ft per minute are provided immediately adjacent to cutting tools or other points of dust generation, and all machining operations are performed inside glove boxes from which air is automatically withdrawn.

Machining Plant at Coventry

A new plant for machining beryllium is now in operation at the Coventry works of Sir W. G. Armstrong Whitworth Aircraft, Ltd. It will produce beryllium components for the fuel elements of reactors such as the A.G.R. This factory has a floor area of about 20,000 square feet. Its layout and services are designed to allow for a doubling of its machining capacity on a dayshift basis and redoubling with full nightshift.

The fact that the company found it necessary to spend about £3 on health and accident safeguards for every £1 spent on the manufacturing plant and equipment emphasises the fact that health hazards associated with beryllium dust caused more concern than did the technicalities of the actual machining operations. Internally the factory is divided into contact areas, in which beryllium is machined or handled in such a way as to require full safety precautions, and non-contact areas where no precautions are necessary, either because the beryllium is always contained in transit boxes or is never present. The contact area is contained in a pressure shell supplied with filtered and heated air which is changed every three minutes. As illustrated here all machining processes are carried out inside completely enclosed machines which are supplied with their own extraction systems working at very high air velocities. All air leaving the building passes through a comprehensive system of absolute filters before being discharged to atmosphere via a 120ft high chimney. The whole building has been designed to prevent any fire hazards from upsetting the elaborate health protection precautions. All furniture, partitions and equipment are made of steel and the building fabric is of fire resistant materials.

Health protection basically consists of preventing beryllium dust coming into contact with an employee. This result is achieved by comprehensive ventilation and extraction schemes and, as an additional safety measure, the wearing of protective clothing, which is washed daily.

An employee enters the beryllium building and goes to the changing rooms where he puts on a complete set of clean free issue clothing, leaving all his own clothing and all personal belongings in his own individual locker before entering the contact area. On leaving the contact area at the end of a shift, an employee removes the issue clothing and takes a shower before putting on his own clothes. All issue clothing worn in the contact area is laundered daily in the beryllium building. No eating or smoking is allowed except in the canteen which adjoins the factory.

Monitoring for air contamination is carried out and a top limit of 2 microgrammes per cubic metre has been set. To avoid risk of interference with monitor sample analysis, a special self-contained health monitoring laboratory has been built 2½ miles away at Baginton. For complete health control all prospective employees undergo a rigorous medical examination—including a chest X-ray. Subsequently periodic medical checks are part of the normal routine. Visitors are allowed into the factory for a maximum of thirty minutes any one day, two periods of thirty minutes within any one week. There is a full-time safety officer in the factory.

In the early stages of operation as a beryllium machining plant the practice is for all operators to wear pressure suits. Then, provided that the monitoring results are satisfactory, it is proposed to use face masks only, for a further test period. Finally, having proved the efficacy of the extraction system by monitoring, masks will be dispensed with and the special clothing referred to above will come into use.

SHORTER REPORTS

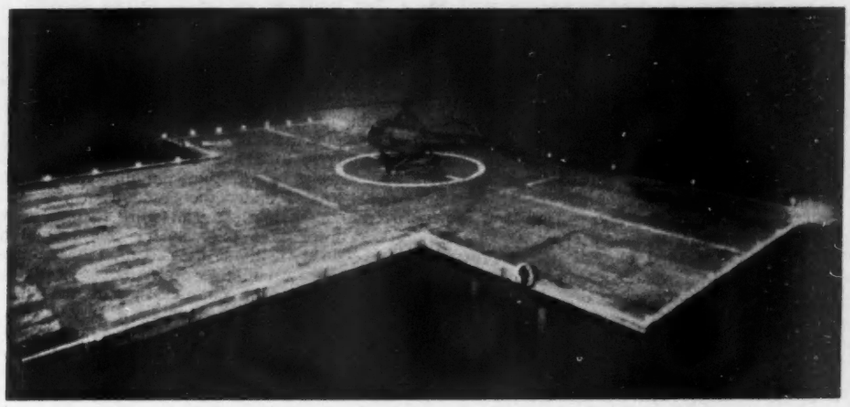
Battersea Heliport Lighting

A LICENCE for night flying has been granted to the London heliport at Battersea after inspection of the installation by the Southern Divisional Controller, Ministry of Aviation, on February 18. The heliport, developed by Westland Aircraft, Ltd., was opened for day flying on April 23 last year, and was illustrated in our issue of May 1, 1959, page 688. Its landing platform, 125ft long by 53ft wide, is built over the River Thames and is connected to the river bank by a taxi strip 65ft wide by 50ft long, leading to the helicopter parking area. Traffic so far has averaged about 150 movements a month—a figure expected to rise to 200 this year. Night flying facilities were necessary to increase the capacity of the heliport.

The lighting equipment was supplied by The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2, to comply with recommendations put forward by the Ministry of Aviation in collaboration with the B.E.A. Helicopter Experimental Unit and independent helicopter pilots. Cost of the installation was about £1700. As seen in the accompanying illustration, the platform is outlined with medium-intensity perimeter lights marking its boundaries and is also floodlit to stand out against its surroundings. By giving texture to the concrete platform, the floodlights help pilots to judge their height on the final approach. Further guidance is given by an angle of approach indicator emitting a flashing signal divided vertically into three coloured zones, the pilot seeing green when on the correct approach path (angled 12 deg. above the horizontal), red if too low and amber if too high.

Red lights are mounted on nearby obstructions, and the corners of the platform are marked by navigation lights to warn shipping.

The perimeter lights are a modified elevated runway light, mounted on the timber fenders which surround the landing platform about 12in below its surface. They are fitted with 6V, 36W lamps which, in conjunction with a one-piece pressed glass refractor, give a maximum intensity in all directions of about 280 candelas. Taxi-track lights are of a special flameproof design because the strip passes close to two underground aviation fuel storage tanks. All perimeter and taxi lights are fed through individual isolating transformers with their primaries connected in series on a ring main cable, supplied with current by a 2·26kVA, 400V-375V main transformer in the switch room below the control tower. Tappings on the main transformer enable the brightness of the lights to be controlled in five stages (100, 60, 30, 10 and 3 per cent) and this facility is used to prevent pilots from being dazzled in the final stages of an approach, when they are landing directly among the lights instead of passing over them as in a fixed wing aircraft.



Helicopter landing platform showing general floodlighting and medium-intensity perimeter lights

On each side of the parking area is a 40ft tower with four 1kW apron floodlights ; two for illuminating the landing platform and two trained on the parking areas. Only one tower is used at a time, according to the direction of approaching helicopters. These lights give an even illumination of 0·5 lumen per square foot on the platform, a level which avoids glare and shadows along the landing area.

Perimeter lights, taxi lights and floodlights are all controlled remotely from a panel in the International Aeradio desk in the control tower. This equipment also controls ancillary lighting, including the 500W low-intensity angle-of-approach indicator, an illuminated windsock, obstruction lights, river navigation lights (for which there are two stages of brightness), apron wall lights and lights for the slipway used by the rescue dinghy.

The lighting system described was put in hand, after trials with experimental lighting under the direction of the overall consultants for the heliport, Messrs. Lewis and Duvivier. All the electrical equipment was installed by Haines and Sheppard, Ltd.

[Reply Card No. E3571]

Additional Traffic Lanes for the Sydney Harbour Bridge

FROM A CORRESPONDENT IN AUSTRALIA

THE Sydney Harbour Bridge, as completed in 1932, provided for six lanes of motor traffic along the centre of the decking, and four rail tracks, two for trains and two for trams, on the western and eastern sides of the main roadway respectively. The progressive implementing of the New South Wales Government policy to replace all trams with buses, led to the closing of the eastern tracks in June, 1958. Under the supervision of the Department of Main Roads several sub-contractors immediately began the task of converting the tracks to two extra lanes for city-bound traffic. This work involved removal of the wooden decking on the main and several approach spans, and the placement of transverse steel girders at 5ft intervals to support the concrete slabs on which the final bituminous surface was to be laid. A ramp has been constructed at the northern end of the bridge to give access to the new lanes from Milson's Point, as the original tram tracks crossed the roadway and were isolated from other traffic for more than a mile north of the main arch.

Six toll-gates for the new lanes have been erected on the site of the old Milson's Point tram platform to supplement the existing barriers at the city end of the bridge, and the new lanes, which will carry only city-bound

Newly-converted tram tracks on eastern side of Sydney Harbour Bridge, looking away from and towards the bridge respectively. The original roadway is seen just beyond the interlane barrier

SHORTER REPORTS *(Continued)*

traffic, are separated from the centre roadway by a concerete barrier. The capacity of the bridge has been increased by an estimated 50 per cent to approximately 10,000 vehicles per hour, and in peak hours six lanes will be allotted to the direction of flow of the main traffic.

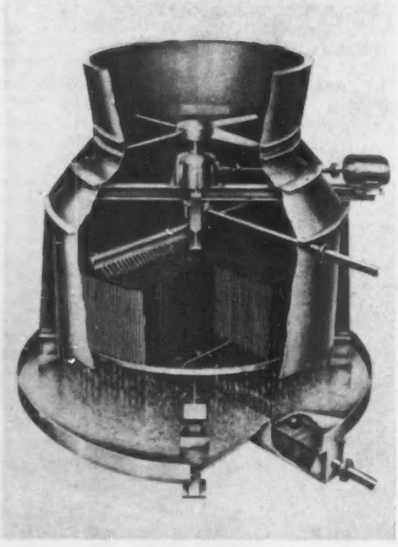
The first illustration shows vehicles proceeding towards the city via the northern toll-gates on the new lanes. Vehicles on the original centre roadway have passed beneath the new lanes and will enter the toll-gates at the southern or city end of the bridge. Milson's Point railway station is in the left background.

The other illustration is a general view looking south towards the main span showing the inter-lane barrier and off-peak traffic proceeding south on the new lanes and in both directions on the centre roadway.

Multi-Channel Cooling Tower

A NEW design of cooling tower, which is claimed to weigh less than half that of a conventional pattern tower, has been developed by Thermotank, Ltd., Helen Street, Glasgow, and the weight reduction has been achieved largely by the use of a new form of fill material. This has been developed by Carl Munters of Sweden, and consists of a plastic impregnated wood cellulose, which combines high resistance to deterioration under severe operating conditions with excellent qualities of water absorption.

Fabricated rolled steel sections, treated against corrosion, form the structure of the tower, which is designed to withstand a wind force of 30 lb per square foot, and the casing is of heavy



Cut-away view of cooling tower showing arrangement of fill and water distribution

gauge galvanised sheets having removable side panels for easy maintenance. The tower is circular in shape, and contains a top-mounted axial flow fan which draws the surrounding air up from the bottom and this cooling air passes through the vertical channels in the honeycomb structure of the fill. This is in the form of thin sheets, alternate flat and corrugated sheets being joined together to form a compact fill having almost tubular passages and providing a large area for heat transfer purposes, while permitting the maximum unrestricted free area for the passage of air per unit volume, since the high wettability of the material ensures that the water adheres to the walls of the channels. Two grades of fill having two sizes of channel are made, the larger having a spacing of a little more than $\frac{1}{2}$in.

The water to be cooled passes through a flanged inlet pipe to a central hub to which is attached a bearing assembly supporting a rotating header pipe. The plain thrust and journal bearings are of plastic impregnated fabric base material with good wet and dry running properties. Along the length of the header pipe are a number of perforations which vary in size to ensure an even distribution of water across the surface of the fill. The header, which rotates under the reaction of the jets, operates at a low static pressure to give large water droplets so that the air can flow at a high velocity without excessive water entrainment. The water flows down the walls of the channels in a thin continuous film and since this is continuously maintained any foreign matter remains in suspension and is drained away so there is no possibility of the channels becoming choked. To prevent any possible accumulation of water at the base of the fill with its resultant restriction of the flow of air, the lower face of the fill is serrated. This breaks the capillary bond and allows the water to run off the tips of the serrations into a catchment tray. The tray is of heavy gauge steel plate and drains into a local sump which is fitted with a pump suction connection, suction screen, drain and overflow connections and a make-up water float valve assembly.

A series of capacity trials carried out by the company has established the relationship between cooling effect, air flow and water flow, &c., and the data so acquired has determined the dimensions and capacity of the range of cooling towers. The trials also confirmed that the new fill does enable substantial reductions to be made in both volume and weight in comparison with existing systems. In particular the resistance of the fill material to acids at normal and elevated temperatures were investigated together with questions of wet strength and shrinkage. Accelerated tests, equivalent to twelve years of normal operation, also formed part of the programme and established that only negligible deposits were formed in the fill despite alternate soaking and drying cycles. It was also found that the impregnation agents in the fill material had an inhibiting effect on bacteria and fungi.

At present the towers are being produced in twelve graduated sizes of which the largest can deal with 90,000 gallons of water per hour with water at 87 deg. Fah. on, and 75 deg. Fah. off, and a wet bulb temperature of 68 deg. Fah. The size of this unit is given as being 20ft in diameter by 12ft in height and weighing 9·5 tons. The comparative figures for a conventional cross flow induced draught tower are said to be, base 32ft 9in by 20ft, height 11ft and weight 27 tons, while those for a vertical induced draught tower are quoted as : base 26ft 3in by 18ft 3in, height 27ft, and weight 29·5 tons.

[Reply Card No. E3581]

High-Efficiency Heating Coil

CHARLTON WEDDLE AND CO., Ltd., Newcastle upon Tyne, has introduced its high-efficiency system of tanker heating in anticipation of a relaxation in the heating surface/cubic capacity ratio criterion for a heating installation. The system, which offers high efficiency through flexibility and improved condensate discharge, is individually designed for each ship on the basis of B.Th.U. output. It is stated that the major obstacle preventing efficient heat transfer in heating coils is the presence of condensate in the steam lines which has to be removed unless output is to be affected adversely. The current method of returning individual exhausts into a condensate header without the use of non-return valves and steam traps is thought to be open to question as is the fitting of valves or traps inside cargo tanks.

In the Charlton Weddle system a patented deck exhaust control unit replaces the conventional header system terminating at the condensate manifold discharge/main condensate return line junction. The manufacturers estimate that for a tanker having thirty-three tanks there will be a capital saving of 40 per cent. The heating coils are of aluminium brass tubing and because of the increased efficiency of condensate discharge, via individual small bore risers direct to the deck exhaust manifold, the heat transfer rate permits a reduced length of heating coil. The installation provides a neat layout of coils at the tank bottom, so that tank cleaning is facilitated, and by unit construction it is claimed reduces installation costs. The system provides greater flexibility of heat application and individual grids may be isolated thus making it possible to reduce the heating surface in accordance with the requirements of viscosity of cargo. Furthermore, should a grid be damaged, tests for oil contamination can be made at deck level and the affected coil closed down.

[Reply Card No. E3582]

Work Loading or Programming Charts

A WORK loading or programming chart based upon the Gantt system has been introduced by New Industrial Charting and Publicity, Ltd., 45, Frederick Street, Edinburgh, 2. This "See How" chart consists of a rigid base board on to which is printed column and row headings and a fine network of graph lines. The board is covered with a transparent sheet and on it the times of jobs are represented by lengths of a special self-adhesive tape having a clean edge, which enables the tape to be repeatedly removed and reattached without damaging either the tape or its adhesive qualities. The tapes are supplied on ruled sheets which can be placed in any typewriter for the information (i.e. job number, machine number, date) to be typed, using an ordinary typewriter ribbon. Ruling on the sheets allows the tapes to be cut exactly to the required length before placing them on the chart.

Before loading, the chart has attached to it a series of red, clean edge tapes, one for each row. Other coloured tapes are then mounted on this red tape, so that after loading, unloaded portions show in red. This red base tape allows rapid rescheduling to be carried out if a machine, for example, breaks down. In such cases the tape can be cut at the point of breakdown and the remainder of the complete row moved forward by moving the red tape to which all the other job tapes are fixed. This design of chart can be readily moved between offices. It is claimed that rescheduling can be effected in a matter of seconds to comply with breakdowns or changes of plans because it is not necessary to move each individual job tape. The tapes are available in nine bright colours and can be cut precisely to length with a razor blade.

[Reply Card No. E3583]

Oil Terminal at Cardiff

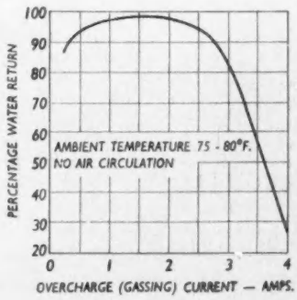
CARDIFF has been chosen as the site for ocean fuel oil terminal, which the Regent Oil Company, Ltd., announced its intention to build towards the end of last year, to serve the industrial areas of South Wales and the Birmingham area of the Midlands. Twelve acres, adjoining the Alexander Dock, have been leased from the British Transport Commission, and for fuel oil storage there will be six tanks to store a total of 168,000 barrels in three grades, together with road and rail distribution facilities. Other tanks will provide for automotive and domestic fuels for the Cardiff area, and there will be eighteen tanks of 42,000 barrels capacity to store light products, and also a lubricating oil warehouse. Contracts for the work have been placed with Whessoe, Ltd., and Constructors, John Brown, Ltd.

Conservation of Electrolyte

THE secondary cell or accumulator behaves, when a state of full charge has been reached, as an electrolytic cell, evolving hydrogen and oxygen at the electrodes. It is therefore accepted that a cell which is kept charged will need periodical topping-up with pure water. Even if the need for maintenance is not a disadvantage, however, trouble may arise from the active agent of the electrolyte—say, sulphuric acid—being carried out of the cells with the gas, and from the fact that the gases are, obviously,

Recombination units in place on a lead-acid accumulator

highly reactive and in stoichiometric proportions. A fundamental solution to these disadvantages has been evolved by Catylators, Ltd., Weydown Road, Haslemere, Surrey, in the form of a catalytic reactor which recombines the oxygen and hydrogen. The catalyst used is palladium, protected against poisoning, enclosed within a porous ceramic chamber ; the hydrogen and oxygen form water vapour in the presence of the palladium and pass through the ceramic to come into contact with the outer envelope of "Polypropylene," which is at close to ambient temperature and acts as a condenser. Since



Performance of A2 "Catylator"

the recombining capacity of the reactor is not infinite (a characteristic is reproduced) and since pressure changes with temperature would be damaging to cell structure, a bleed valve communicating with atmosphere is provided. Clearly, this device does not prevent loss of water vapour due to over-temperature, but to suppress this effect would require the battery to be redesigned. "Catylators" are available to take the place of all vent plugs except the smallest ; the performance illustrated is intended for use with the prevailing voltage control charging circuits and can be modified to improve the return at either high or low currents if the application so requires.

[Reply Card No. E3591]

Bell Furnaces for Heat Treating Stainless Steels

AMONG the new plant installed in recent years at the works of Shepcote Lane Rolling Mills, Ltd., Sheffield, there are four electrically-heated bell furnaces for treating stainless steel coils, which have been supplied by G.W.B. Furnaces, Ltd., Dudley, Worcs. These furnaces, the last of which was installed a few months ago, were each provided with two charge bases, a slow cooling hood, automatic temperature control equipment and switchgear.

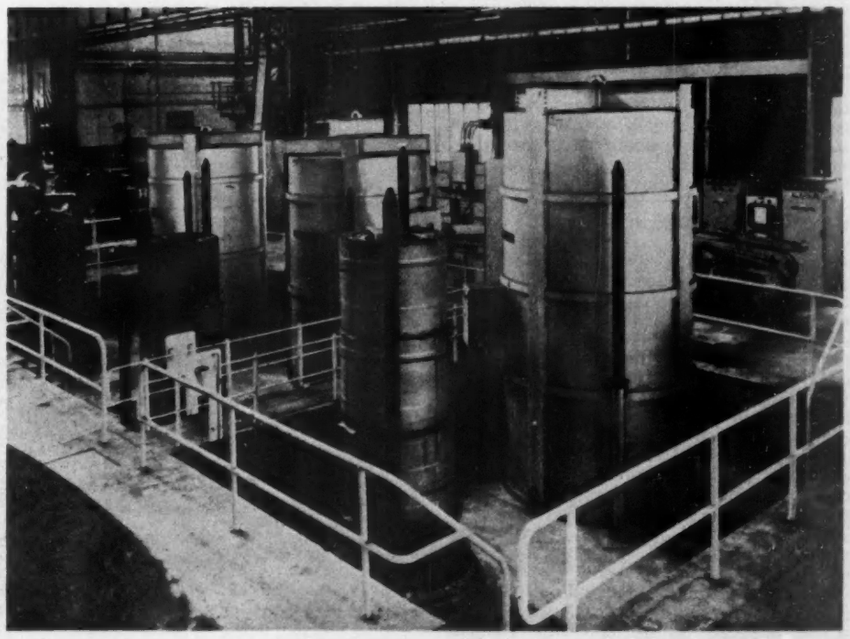
The furnaces, as shown in an accompanying illustration, are installed together in the softening and descaling section of the mills. Materials treated are Firth-Vickers F.I. 17 and Samuel Fox's SF. 17 stainless steels. Slabs of stainless steel weighing approximately 2 to 3 tons are hot rolled to a gauge of approximately 0·128in, the ends of the coils thus produced then being cut off and the edges trimmed. Strip from two or more slabs is butt welded together to obtain a coil of approximately 5 tons ; coils vary in diameter up to 54in with widths ranging from approximately 24½in to 40½in. After hot rolling and building up, coils are softened in the bell furnaces to remove residual hot rolling stresses prior to descaling and cold rolling to lighter gauges.

The furnace casings are fabricated from rolled sections of sheet steel formed into a cylindrical shell, heavy cross bracings being fitted into the roof of the bell to ensure rigidity during hoisting. A lifting attachment is situated on the roof of the casing with a hook arranged for straight pick up from the shop crane. Tubular members, fitted to the furnace casing, are arranged to slide over base guide posts in such a manner that the bell does not tilt over and come into contact with the charge. The heating chamber is lined with refractory element firebricks backed by a thickness of insulating material and heating is provided by heavy nickel-chromium strip elements in sinuous form arranged around the wall of the chamber. Each base is fitted with an electrically-driven air circulating fan which sucks the air through the centre of the coils and blows it up around the outside and over the heating elements situated around the wall of the furnace. Uniform thermal conditions are essential in this process in order to obtain uniform metallurgical conditions throughout the strip, and forced convection not only ensures that these conditions are obtained but also reduces heating up times. Each base is provided with pick-up contacts to mate up with those fitted on to the heating bell. The contacts are enclosed in sheet steel covers arranged to open and close automatically as the heating bell unit is raised and lowered.

The whole charge weight is taken on a cast heat-resisting steel stool fixed into the hearth brickwork. The bases of the two earlier furnaces were designed to carry two coils with a total maximum weight of approximately 10 tons, whilst the larger, more recently installed furnaces can accommodate three coils weighing approximately 15 tons. Previously, the coils were loaded individually on a cast heat-resisting steel jig with radial supports underneath and a central column running through the middle of the coil with an attachment at the top for lifting. Now that larger coils are being manufactured, it has been found more satisfactory to use a mechanical tongue fixture which is dropped around the coil by the overhead crane and, on being raised, the jaws clamp around the coil giving a simple lift with the minimum of delay. The absence of the jigs cuts down the heating of unproductive metal and increases the possible loading height. The rating of the earlier two heating bells is 220kW arranged in a single automatically controlled zone reducible to 110kW during the soaking period ; that of the more recent furnace is 260kW, reducible during soaking to 130kW. Each furnace is designed for a maximum temperature of 950 deg. Cent. although the normal working temperature is approximately 800 deg. When the soaking period is completed, the heating bell is lifted off and transferred to another base where another charge has been loaded. Thus continuous working of each furnace, in conjunction with its two bases, is assured.

Instrumentation includes Kent indicating controllers fitted with contacts to reduce the furnace ratings when the preset temperature has been reached, and Kent three-point recording instruments giving a positive check of thermal conditions on any of the bases and on the heating bells themselves. Wall mounting cubicles, housing the rating reduction contactors, are mounted on the sides of the furnace casings, whilst switchgear is contained in separate totally enclosed cubicles.

[Reply Card No. E3592]



Bell furnace installation at Shepcote Lane Rolling Mills, Ltd.

SHORTER REPORTS *(Continued)*

Computer Bureau in Birmingham

FACILITIES at the Midland Data Processing Bureau in Birmingham of International Computers and Tabulators, Ltd., Gloucester House, 149, Park Lane, London, W.1, have been extended by the installation of an I.C.T. Type 1202 electronic computer. The bureau, at 18, Digbeth, Birmingham, 5, maintains a service to industry which has been provided in the area for some twenty-five years by punched card data processing, and is fully equipped with machines of this kind, supplemented by an electronic multiplier for longer calculations. With the installation of the Type 1202 machine it has become the first electronic computing bureau to be established in the Midlands. The new service was formally inaugurated on February 22 by Sir Edward Boyle, M.P., Financial Secretary to the Treasury.

Electronic computer installation at data processing bureau, showing input/output equipment in foreground, and left to right at rear, the control console, arithmetic unit and drum storage/power supply unit

The computer is available for use by the company's customers to supplement their own resources, to test programmes, or to undertake special tasks required urgently at short notice. It will also serve for training the company's and its customers' staffs, and will perform general computing services for others. Hiring rates are £24 an hour, or £25 an hour with operator. A programmer's services are available at £2 an hour. Normally, however, customers supply their own programmes in a form similar to a flow chart, and cards are punched from these data at the bureau.

The Type 1202 electronic digital computer is the latest development of the 1200 series, of which about sixty have been installed. It still ranks as a small, general purpose machine, differing from its predecessors mainly in the increased capacity of the magnetic drum, which will store 4096 words on 256 tracks, sixteen words per track. Basic word length is forty binary digits. Drum speed is 3000 r.p.m. and word transfer time 1·25 milliseconds. Valve circuits are used throughout. Input to the computer is in the form of I.C.T. eighty-column cards, which are fed to a card reader operating at 100 cards a minute. Output mechanisms, seen in the foreground of our illustration, consist of a line printer and a card punch, operating at 100 lines and 100 cards a minute respectively. There is direct transfer from card reader input to line printer output for all notations except binary.

A demonstration of the logical powers of the computer was given last week, when it was shown operating as an automatic planning office, fitting orders into a future production plan so as to use machine tool capacity to the best advantage, while providing the earliest completion dates consistent with this consideration. Two groups of cards form the input for this operation, one giving standard information on the products and the other containing variable information punched from orders and inquiries. Standard information cards are assembled with the variable cards and fed into the computer, which first examines the required manufacturing operation and multiplies the quantity of articles required by the time allowed per piece. Setting time and, if necessary, interval time, are added and a process time is produced. The next computer step loads this time on to the current manufacturing programme and, where the load is in excess of capacity, transfers a proportion of this load to the next manufacturing period, and so on. Finally the computer presents the results of its calculations and loading operations in the form of a slip showing description of product, product number, order number, quantity, and period due.

The Birmingham installation is the first step in the provision of electronic computers at I.C.T. service bureaux, and it was stated during the demonstration and inspection last week that a new transistorised computer with magnetic tape input, developed in collaboration with Computer Developments, Ltd., will be announced shortly. Work is proceeding on an auto-code which would enable users to write their programmes direct in a form acceptable by this machine.

[Reply Card No. E3601]

Pressure-Vessel Lifting Operations at Hunterston

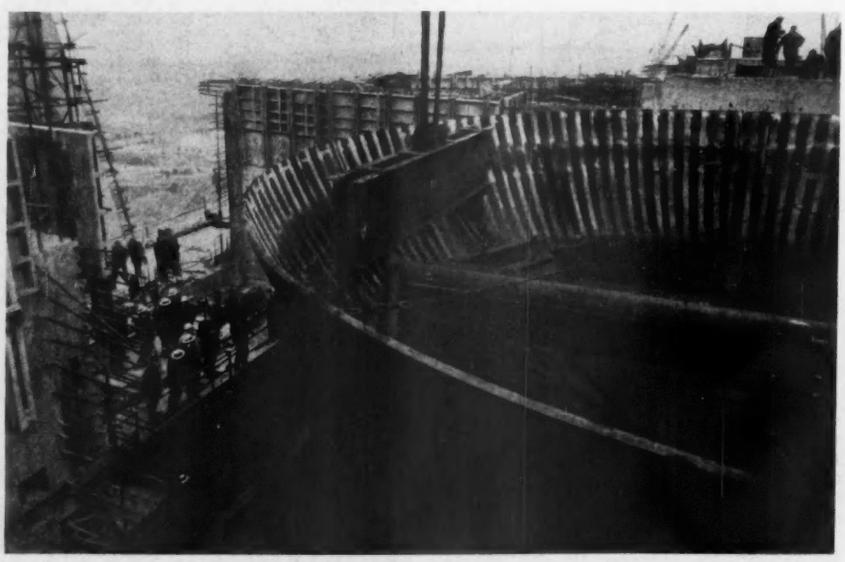
WITH the full scale resumption of work on the Hunterston nuclear power station site, good progress is now being made on the pressure vessel construction and other steel fabrication that had been held up during the recent labour dispute. One of the first major jobs to be tackled was that of turning over, and lifting into the biological shield, the complete bottom head and support course of the 3in (76mm) thick steel pressure vessel for reactor "A." This has been followed in the last few days by the 70ft (21,340mm) diameter third course.

The operation of lifting the bottom head and support course as a single unit demonstrated the capacity of the "Goliath" crane, and the precision of its control. The unit, with its lifting beams, weighed 320 tons (325 tonnes), the overall diameter being 66ft (20,120mm). There are 120 slotted gusset plates, welded on the outside, on a pitch-circle diameter of 62ft (18,900mm), and the unit had to be positioned so that these slots would fit smoothly over the outer skirt, which was already in position inside the reactor vault. Only $^{1}/_{32}$in (0·8mm) clearance was available in each slot.

Much of the preparatory work had been done when operations were suspended last September; the bottom head had been welded in an inverted position on the special prefabrication area between the steam-raising-unit fabrication workshop and reactor "B." It had then been lifted on to the completed support course, the two welded together, the gusset plates attached, and the slots accurately cut. Very shortly after work on this part of the contract had started again, the complete unit was turned over by the "Goliath" crane. A few days later, when weather conditions were suitable, it was lifted by the crane, carried over the partly finished structure of reactor "B," and lowered into place on the outer skirt inside the biological shield of reactor "A." This operation (a stage of which is illustrated here) was completed in about two hours.

Welding of the gussets to the outer skirt was then begun; after completion of this welding, the next course, weighing 240 tons (244 tonnes), was lifted into position.

Over 500 men are now working again on site for the Motherwell Bridge and Engineering Company, and three shifts a day are being worked. The main contractor for the Hunterston Nuclear Generating Station, which is being built for the South of Scotland Electricity Board, is The General Electric Company, Ltd., of England, a member of the G.E.C.–Simon-Carves Atomic Energy Group.



The 320-ton bottom head and support course of the first reactor pressure vessel for Hunterston nuclear generating station being lowered by the Goliath crane into position inside the biological shield

Container Handling Crane

A SPECIAL design of crane for handling containers has been developed by Steels Engineering Products, Ltd., Crown Works, Sunderland, for Anglo-Continental Container Services, Ltd. Two of these cranes have been built, one being installed at Ardrossan in Scotland, and the other at Larne in Northern Ireland. Four ships are used in this container service and at the ports high-speed fixed equipment handles the containers between the ships and quayside. The cranes, supplied by Steels Engineering Products, Ltd., have been introduced to transport the containers between the quay and parking sites, where they are loaded and unloaded on to vehicles for road transport. These cranes are designed to work in narrow aisles between rows of containers, slew through a full circle, and handle the 20ft long, 12½-ton containers in such a way that they do not sway and are held almost vertical when being transferred to and from the road vehicles.

The special cranes are based upon the maker's "Emperor" diesel-electric mobile crane, which instead of having the conventional strut jib is fitted with a lifting mast of "hammer head" design, as can be seen in our illustration. This mast is hinged at its lower end on support brackets at the front of the superstructure. A welded steel carriage for containers projects horizontally out from the mast, on which it is raised and lowered by a hoist-rope passing over pulleys on the mast-head crosspiece. Four rollers on the carriage run in the main vertical channel of the mast which acts as a guide-way and permits a smooth hoisting and lowering action. By tilting the mast a few degrees so that the load rests against a pad on the carriage swinging of the container is prevented. Hydraulically-operated telescopic backstops are fitted to prevent the mast being tilted more than 7½ deg. beyond the vertical position.

For this particular application the maximum lifting capacity of the crane, which is based upon two-thirds of the tipping load, is 12½ long tons at a radius of 11ft 3in at which the lifting mast is in the vertical position required for normal operation.

The enclosed driver's cab at the front of the revolving superstructure gives an unrestricted view of the working area. All crane motions are operated from this cab and the layout of controls has been arranged to give swift and effortless operation. A lever for each motion is incorporated in a console in front of the driver: to operate any motion he selects the appropriate switch and moves it up or down, depending upon the direction required. Speed of motion is thereafter controlled by use of the engine accelerator.

[Reply Card No. E3611]

Catamaran Firefloat "B.P. Firemaster"

To combat the special fire hazards present within the dock area during the unloading and loading of crude oil and oil products, there has recently entered into service in Swansea Docks the firefloat "B.P. Firemaster." This craft, of unusual appearance, has been designed by the engineering department of the B.P. Tanker Company, Ltd., and is based on the experience of the department with other fire-fighting craft. It was realised that while tugs, properly equipped, have their value as fire-fighting units, their dual role makes them uneconomic for working in the docks. The main disadvantage, however, is that the reaction from the water jets pushes the tug away from the fire unless it is fighting the fire from a head-on position and able to use its engines to maintain position. Even the head-on position cannot be held in a cross wind. It was with these points in mind that the decision was taken to build a single-purpose vessel and so overcome the shortcomings of the orthodox tug.

The firefloat, which we illustrate, was built by R. S. Hayes (Pembroke Dock), Ltd., for service in the Swansea Docks and combines mobility with a high fire-fighting potential and the ability to maintain position alongside a burning vessel without the need to moor. The hull consists of two pontoons, each 60ft long by 14ft wide by 7ft 6in deep, which are joined at deck level and are also joined below water by elliptical tubes to form a catamaran having an overall breadth of 36ft. Mounted on the deck is an open pyramid, formed by four steel tubes, at the apex of which is the control cabin from where the fire-master directs operations. Below the cabin are two rectangular platforms located respectively at 30ft and 23ft above the water line and arranged with diagonals sited forward and aft and athwartships. Four monitors are mounted on each platform in the port, starboard, forward and aft positions, while a ninth monitor is placed on the roof of the control room 40ft above the water line. The arrangement is such that seven of the nine monitors can be used in any one direction and the height of the control tower monitor ensures that water or foam can be directed on to the deck of a tanker at whatever state of its loading.

Propulsion of the firefloat is by two "Harbormaster" outboard power units, one at each end of the float, and each is driven by a Dorman K.U.D. six-cylinder diesel engine of 140 b.h.p. and fitted with Bryce Berger "Handraulic" starting equipment. Both propulsion units can be started and controlled from the wheelhouse and each propeller can be rotated through 360 deg., so that the firefloat can be moved in any direction and held in any position against the thrust of the monitor jets. A special point of interest is the mounting of large pneumatic wheels at the ends of the pontoons, thus facilitating movement along the side of a burning vessel.

The layout of the fire-fighting gear has been designed in collaboration with Merryweather and Sons, Ltd., and the requirements of the nine 4in gear-operated fire-fighting nozzles are met by two Merryweather two-stage turbine pumps, each driven by a 6.Q.A. Dorman diesel engine developing 215 b.h.p. The output of 3100 gallons per minute at 100 lb per square inch, or 12,500 gallons per minute of foam is delivered to the monitors through a central rising main. The pumps are housed in pump rooms within the hull and at the ends of each pump room are foam compartments with buoyancy spaces at the ends of the pontoon completing the subdivision. From each pump there is an 8in deck suction fitting which enables the pumps to be used for salvage purposes. A motor-driven Gilkes Gordon bilge pump and a motor-driven Hamworthy foam pump completes the equipment.

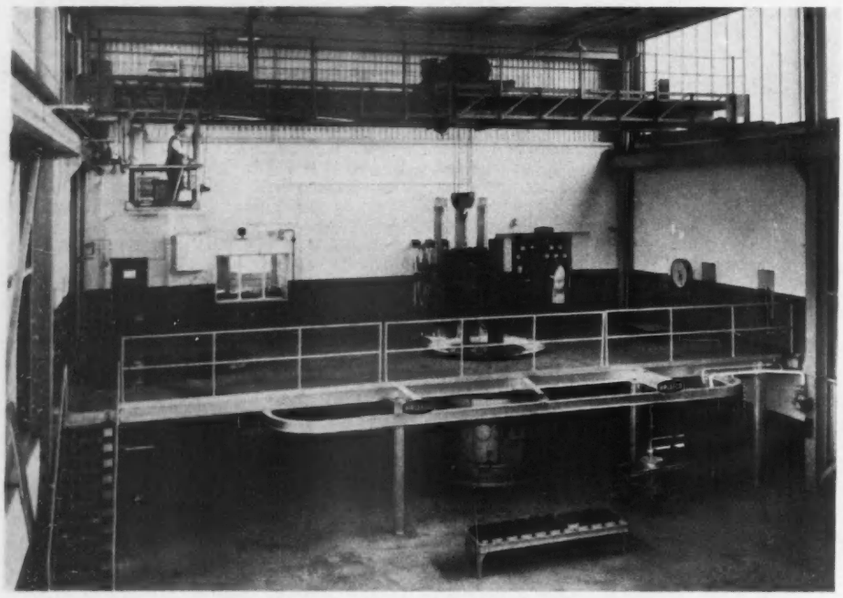
On the main deck between the pump room skylights is a house consisting of a well-fitted-out cabin and adjacent galley, with a cross alleyway giving access to port and starboard pump rooms. A Marconi loud-hailer talk-back system is installed between the control cabin, monitor stations, wheelhouse and pump rooms, while instruction to the pump rooms can be given from the control cabin by electric telegraph. The firefloat will be moored by quick release ropes and have a regular crew of two, so that the fire pumps and propulsion units, all of which are push-button started, can be ready for action immediately the fire-fighting personnel are on board.

[Reply Card No. E3612]

Specially equipped mobile crane loading container on to a road vehicle

Firefloat "B.P. Firemaster" on trial

SHORTER REPORTS *(Continued)*



Pilot smelting plant operating platform. Adjustment is being made to the setting of one of three amorphous carbon electrodes by the 5-ton overhead travelling crane

Pilot Electric Smelting Plant and Service

AN electric smelting plant has been laid down by Birlec-Efco (Melting), Ltd., Westgate, Aldridge, Staffs, to provide any firm contemplating the installation of electric smelting equipment with facilities for assessing in a pilot plant the practicability of its plans without need for capital expenditure. With this service a firm can submit trial batches of new material for testing their amenity to electro-thermal reduction and for determining the most suitable smelting technique as well as the nature of the resultant products. In addition to many other electro-thermal processes the new plant is capable of smelting calcium carbide, iron ores and manganese ores ; the production of ferro silicon and ferro-chrome ; extraction of nickel and copper concentrates ; and the treatment of slags.

The pilot plant, to be seen in our illustration, has been installed in a new 5700 square foot building, incorporating storage facilities for refractories, electrodes, and raw materials ; a laboratory ; and ancillary equipment for crushing, ladle heating and casting. The furnace installed has an 8ft diameter shell, and its normal rating is 350kVA, there being a wide range of voltage tappings to cover a majority of electric smelting operations. It is designed for working temperatures up to 2000 deg. Cent. The furnace structure is mounted in a charging platform ; it can be operated as an open-top unit or its top can be fitted with a roof. Three tap holes in the furnace can be arranged as required to suit different levels for slag and metal removal. Slag pots and ladles are slung from a mono-rail supported from the underside of the charging platform and extending right round the furnace installation. Whilst the furnace is in operation fumes are extracted through on annular duct round its upper circumference and taken through a water wash installation before discharge to atmosphere.

The furnace shell assembly is mounted on a heavy circular ring through which it is supported by rollers on foundation brackets. Fixed to the base of the shell within its support ring is a gear ring meshing with a pinion driven by a variable speed gear and motor. Through this drive the furnace can be rotated or oscillated at selected speeds during tests. The electrode holders of the furnace have pneumatically-operated clamps and take either amorphous carbon or graphite electrodes 8in diameter, provision being made for the fitting of holders for smaller electrodes when necessary.

The substation, which is integral with the main building, houses the high voltage contactor, the furnace transformer, a 0·7kW amplidyne electrode controller and a low-tension distribution board. A B.T.H. three-phase transformer, nominally rated at 350kVA, has an ancillary cooler which enables higher outputs to be attained for special smelting applications, full output being available on all secondary tappings. Its secondary windings can be connected in series or parallel. With series connection there is available a voltage range of 250V/130V in twenty steps, and with parallel connection the range of 125V/65V can be obtained in ten steps. This transformer has a nominal reactance of 5 per cent at maximum secondary voltage and current.

A tapped reactor to provide arc stability for special work provides a number of equal steps which can be pre-selected with any value of voltage by the common motorised tap-change switch. In addition to this switch for normal operation there is an emergency hand tap-change control interlocked with the circuit breaker to ensure off-circuit operation. Power supply to the furnace is by a high voltage contactor and an oil circuit breaker which gives protection against short circuit and excessive overload. Under-voltage protection is provided in the contactor.

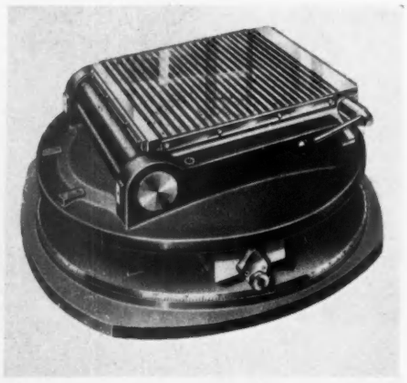
[Reply Card No. E3621]

Re-Equipment of Aluminium Works at Kitts Green

To meet present and future demands for aluminium alloy plate and sheet, and to effect economies in production costs, James Booth Aluminium, Ltd., has planned an extensive re-equipment and expansion programme at its Kitts Green Works, Birmingham. The complete scheme is estimated to cost £5,000,000, and planning has made such rapid progress that the stage has been reached when decisions regarding the mechanical side of the new plant could be made. The order for this equipment, to the value of about £1,500,000, has been placed with the Loewy Engineering Company, Ltd., Bournemouth. This new mill will roll ingots weighing up to 6 tons, for the casting of which equipment already exists at the works, for the production of plate, sheet and strip. The plant has been designed to have a capacity sufficient to meet any foreseeable increase in demand, and includes a reversing four-high hot mill, having 38in diameter work rolls and 60in diameter back-up rolls of 148in barrel length. There will be a heavy vertical mill for rolling the edge of thick plate and a shear able to deal with plate up to 4in thick. Within the limits imposed by the maximum size of billet, namely 6 tons, the mill will be able to produce plate up to 6in thick, 12ft wide, and 50ft in length. The mill will break down slab ingots into strip which will be finished rolled in a single mill stand in the run out of the plate mill. It is planned that the latter unit will be replaced in the future by a three-stand tandem mill. In addition to the hot mill there will be installed a modern four-high cold reversing mill to produce strip 64in wide and down to 0·012in thick. The cold mill has work rolls of 16½in diameter and back-up rolls of 44in diameter by 72in barrel length.

Permanent Magnet Sine Angle Chucks

THE rotary compound sine angle permanent magnet chuck shown in the illustration below is now made by Darwins, Ltd., Fitzwilliam Works, Sheffield. It consists of a 14in by 12in permanent magnet chuck mounted to rotate up to 90 deg. about an upper horizontal axis and up to 47 deg. about a lower horizontal axis set at right angles to the upper axis. The chuck and its base support plate are arranged to form 10in sine bars by which angles about both axes can be set with slips.



Rotary compound sine angle permanent magnet chuck

When setting the chuck is first tilted to more than the required angle and the slips inserted ; the chuck is then lowered through its screw operated tilting mechanism to nip the slips. Angles about the lower axis are set in a similar manner. Degree divisions are provided for setting the unit about its vertical axis, but for high-precision setting the sine bar support enables a 10in sine bar to be inserted on its side.

This firm has also introduced a plain sine angle magnetic chuck, with a 10in by 6in, or a 14in by 6in chuck, which can be rotated from $-\frac{1}{2}$ deg. to $+46$ deg. or $+61$ deg. about a horizontal axis.

[Reply Card No. E3623]

INDUSTRIAL NEWS

Overseas Trade

Exports of United Kingdom goods and manufactures in January were valued at £316,300,000. The value of imports in January was £367,300,000 and of re-exports, £12,000,000. The Board of Trade says that, after eliminating normal seasonal variation, exports in the three months, November, December and January, were 7 per cent above the average monthly value for 1959. On the same basis, imports were 10 per cent above the monthly average.

The Board of Trade has stated that, in the final quarter of last year, there was a marked increase in the volume of the United Kingdom's exports and imports. In that quarter, the volume index (1954 = 100) was 125 for exports and 130 for imports, both markings being 8 per cent above those for the comparable quarter of 1958. All classes of United Kingdom goods and manufactures showed increased export volumes in the last quarter of 1959, as compared with the preceding quarter and with the last quarter of 1958. Among manufactured goods, the four classifications, namely, road vehicles and aircraft, machinery other than electric, chemicals, and iron and steel, were the most influential in contributing to the increase when compared with a year earlier. That trend has obviously continued in the early weeks of the present year.

Scientific Management

The twelfth International Congress of Scientific Management is now in session at Sydney, Australia. It began on Tuesday last with an address by Lord Baillieu, president of the British Institute of Management. His subject was "The Next Ten Years in Management."

In his address, Lord Baillieu described the 1950s as the period of man's greatest economic growth, a factor which, he said, was of great significance when it was remembered that the 1950s covered a period immediately following a major world war. The 1960s, he added, had begun with the industrialised countries of the world in a greatly strengthened position. Lord Baillieu went on to some observations about underdeveloped countries, saying that investment and financial aid were not their only requirements ; more technical assistance and skilled manpower were also needed. It was relatively easy, he remarked, to ask countries to provide financial aid, but it was people that really counted. Advanced countries, he urged, would have to realise that in the long run it was to their advantage to provide such aid. In the past, Lord Baillieu continued, two fairly distinct classes of country had developed, namely, the industrialised country and, at the other extreme, the country producing little but food and materials. The manufactures exported by the one and the food or material exported by the other were handled by merchants, and the industrial managers in the advanced countries had as little need to know about the less advanced country as the primary producer had to know about industrial conditions in his eventual market. But the situation was developing and would continue to do so in the 1960s. Countries which, until recently, had regarded themselves as under-developed now had many industrial plants, and the growth of industry throughout the world was forcing managers to be very international in outlook.

It was now almost impossible, Lord Baillieu observed, to separate the economic, social and political factors which played such a large part in the life of a firm. Action by Governments might have vital consequences for industrial or commercial firms and those actions were themselves extremely sensitive to the main currents of public opinion. A change of fiscal policy might affect confidence and disturb markets and working conditions in industry, and political disputes might lead to measures which had serious repercussions on the prosperity of many industrial, financial or commercial concerns. Whatever the method employed, Lord Baillieu asserted, most Governments in economically advanced countries were now committed to a policy of maintaining a high and stable level of employment, and all were committed to maintaining orderly economic growth and to the stimulation and diversification of their own and their neighbours' economies. Management, Lord Baillieu added, could benefit only if it recognised and accepted that the public and private sectors of the economy constituted a partnership, one that was vital to the prosperity of each and to the vigorous development of the economy as a whole. It was that situation, Lord Baillieu declared, which would create the opportunities of the second half of the century.

Launches in 1959

Lloyd's Register of Shipping has issued its *Annual Summary of Merchant Ships Launched in the World during* 1959, and the total for Great Britain and Northern Ireland is 274 ships of 1,372,595 tons gross, and equivalent to 15·7 per cent of the world output. The total includes fifteen ships of 15,000 tons and upwards, and forty-nine oil tankers of 528,928 tons representing 38·5 per cent of the total output. Tonnage for export amounted to 115,482 tons, or 8·4 per cent, and represented a reduction of 222,416 tons on the 1958 figures. A total of 449,073 tons were launched abroad for registration in Great Britain and Northern Ireland so that this country was a net importer of tonnage, the excess of imports being 333,621 tons.

Safety in Diving Operations

Proposals for a safety code for persons employed in diving operations at any place to which the Factories Act, 1937, applies, are laid down in the Draft Diving Operations Special Regulations which have been published by the Minister of Labour this week. These draft regulations provide that no person shall be employed as a diver unless either he has had previous experience and a knowledge of diving practice, including decompression procedure to the depth to which he is to operate, has an understanding of the operation, the apparatus in use, and the apparatus available for use in an emergency, or if undergoing training he is working under the immediate supervision of a diver who fulfils these conditions. The Regulations also set out the safeguards to be observed during diving work and require that plant and equipment shall be thoroughly tested before being brought into use. The equipment must be examined at least once every three months and a register of tests and examinations has to be kept. No person may be employed as a diver unless he has been medically examined and declared fit for the work, and provision is also made for periodic medical examinations of divers and for the maintenance of a register of fitness relating to them. Comments on the draft regulations are invited from organisations and individuals who may be affected by them. These should be sent to the Ministry of Labour, 8, St. James's Square, London, S.W.1, before March 16.

Ergonomics in the Control Room

The three-man team of U.S.A. consultants which, as reported in our January 29 issue, has been analysing the "human engineering" (ergonomics) aspects of nuclear power station control rooms at the Erith atomic energy headquarters of The General Electric Company, Ltd., completed its studies this week. At a Press conference on Wednesday its members were introduced by Dr. K. J. Wootton, Manager, G.E.C. Atomic Energy Division, who said the company had thought it very desirable to look at the problem from the point of view of "the driver." They were continually encouraged to put more and more instruments into the control room, sometimes without much regard to how much people read them. Dr. Jerome H. Ely, leader of the team and an assistant vice-president of Dunlap and Associates, the consultants, said their purpose had been to examine the proposed design for Sizewell power station. Taking existing forms of instrument display as an example, he showed how dials could be arranged and pointers aligned so as to take advantage of the human capacity for recognising patterns in the rapid detection of variations from normal. On a longer view, they made recommendations for the control rooms of the future, in which a more restricted instrumentation would show changes of state rather than instantaneous conditions, and audible alarms would compensate for the limitations of the human being as a monitor. They needed good men in the control room, but good men might get bored, and one way to combat this was for control staff to be rotated through various jobs at the station. Change of posture also reduced tedium, and a control desk had been designed which could be operated either seated or standing, with similar reach to all parts, which had a further advantage in that men tended to stand up in an emergency. Dr. Ely suggested there should be a computer in every power station, which could be used by the station physicist, afford continuous training exercises for the staff, and provide the predictions required by the human operator in making decisions which would still be his responsibility.

PERSONAL AND BUSINESS

Appointments

MR. S. J. BURTON has been appointed export sales manager of Chaseside Engineering Company, Ltd.

THE U.A.M. GROUP has appointed Mr. P. E. Gargrave as a representative for the south-west and west London area.

MR. TOM TAYLOR has been appointed works manager of the Glanamman, Carmarthenshire, factory of Crompton Parkinson, Ltd.

PERKINS ENGINES, Ltd., announces that Mr. B. A. Chengapa has been appointed assistant liaison executive in India for the company.

MR. PETER WRIGHTSON, managing director of Head Wrightson and Co., Ltd., has been appointed vice-chairman and managing director.

MR. E. M. WHITAKER, A.M.I.E.E., has joined Associated Electrical Industries (Woolwich), Ltd., as assistant to the commercial director.

MR. JAMES ROBERTSON is to be released from his executive position as chief production engineer of Simms Motor Units, Ltd., to become special technical assistant to the managing director.

VAUXHALL MOTORS, Ltd., states that Mr. K. M. Eaton has been appointed general supply manager, with effect from March 1. He succeeds Mr. G. F. Tipler, who has requested early retirement.

MR. J. MACKENZIE-MAIR has been appointed to the board of Steel, Peech and Tozer, a branch of The United Steel Companies, Ltd., and has assumed the title of director and commercial manager.

MR. E. S. SELLARS has joined the British Petroleum Company. He will become manager of the petroleum division of the company's Sunbury research centre in succession to Mr. W. M. Catchpole, as from March 28.

A. REYROLLE AND CO., Ltd., has announced the appointment of Mr. C. H. Lackey, M.I.E.E., as protection manager, to be responsible for all aspects in the development of the company's relay and protection business.

BRITISH TRANSPORT COMMISSION announces that Mr. A. E. Flaxman, commercial officer, British Railways, Western Region, has been appointed to succeed Mr. A. A. Harrison, chief freight officer, British Railways Central Staff.

THE RT. HON. THE VISCOUNT CHANDOS, chairman of Associated Electrical Industries, Ltd., has been appointed president of the Locomotive and Allied Manufacturers' Association of Great Britain for 1960. Mr. G. Collingwood, managing director of The Vulcan Foundry, Ltd., has been appointed chairman of the Association.

THE GENERAL ELECTRIC COMPANY, Ltd., announces three new appointments at the company's engineering works at Erith, effective from April 1. Dr. K. J. Wootton, M.I.Mech.E., has been appointed manager, and Mr. C. J. O. Garrard, M.I.E.E., deputy manager of Erith Works. Dr. H. K. Cameron, M.I.E.E., has been appointed manager of the atomic energy division, Erith.

DR. J. N. ALDINGTON, M.I.E.E., an executive director of Associated Electrical Industries, Ltd., has been appointed a director of Henley Foundries, Ltd., and elected chairman of the board. Following the death of Mr. K. B. McCreddie, sales manager, on December 25, 1959, Mr. R. S. Lane has been appointed commercial manager, and Mr. C. M. Grant, sales manager, of Henley Foundries, Ltd.

THE MARTIN-BLACK GROUP OF COMPANIES has announced the following appointments made by Martin, Black and Co. (Wire Ropes), Ltd., and the Speedwell Wire Company, Ltd.: Mr. J. McVey, with the title of production manager, becomes personal assistant to Mr. Alex Johnston, works director; Mr. J. Gardiner becomes chief wire planner; Mr. W. McKenna, chief rope planner; Mr. J. Miller, wire production manager, and Mr. H. Weir, rope production manager.

THE MINISTRY OF TRANSPORT announces that Mr. C. E. Hollinghurst, A.M.I.C.E., has been appointed a deputy chief engineer (civil) on the highways engineering staff at headquarters. Mr. J. A. S. Dakers, A.M.I.C.E., has been appointed to succeed Mr. Hollinghurst as divisional road engineer, Metropolitan division. Mr. H. S. Keep, M.I.C.E., has been appointed an assistant chief engineer at headquarters and has been succeeded as divisional road engineer, south-eastern division, by Mr. T. E. Hutton, M.I.C.E. Mr. L. P. F. Hubbard, A.M.I.C.E., has been appointed divisional road engineer, south-western division, in succession to Mr. Hutton.

ASSOCIATED ELECTRICAL INDUSTRIES, Ltd., has announced the following appointments: large steam turbine department, Mr. J. S. Hall, A.M.I.Mech.E., chief engineer; Mr. J. C. London, assistant chief engineer (development). Small steam turbine department, Mr. P. D. Morris, M.I.Mech.E., chief engineer (direct coupled sets); Mr. F. D. Roberts, chief engineer (geared sets). Gas turbine department, Mr. F. R. Harris, A.M.I.Mech.E., chief engineer; Mr. H. Farrington, A.M.I.Mech.E., assistant chief engineer. Mechanical engineering development department, Dr. K. W. Todd, M.I.Mech.E., assistant chief engineer (fluid and heat flow); Mr. H. B. Svendsen, assistant chief engineer (mechanical). Nuclear auxiliaries department, Mr. T. E. Adams, chief engineer. Turbo-generator department, Mr. H. I. Wood, A.M.I.E.E., chief engineer (large machines); Mr. F. R. L. Creek, A.M.I.E.E., assistant chief engineer (large machines); Mr. J. Scott, chief engineer (medium machines).

Business Announcements

THE MINISTRY OF TRANSPORT has established a new London Traffic Management Unit and has appointed Dr. G. Charlesworth as its head.

SIMMONS AND HAWKER, Ltd., has completed its transfer from Wandsworth, S.W.18, to Central Way, North Feltham Trading Estate, Middlesex.

BRITISH OXYGEN AVIATION SERVICES, Ltd., Western Industrial Estate, Harlow, Essex, has instituted a series of specialist courses on aircraft liquid oxygen breathing systems.

MR. E. W. H. GIFFORD has now taken into partnership Mr. J. R. Lowe and Mr. H. E. Lewis, under the style of E. W. H. Gifford and Partners, consulting engineers, Carlton Lodge, 16, Carlton Crescent, Southampton.

NEWTON CHAMBERS AND CO., Ltd., states that with effect from March 1, the name of The N.C.K. Rapier Sales Company, Ltd., is to be changed to N.C.K.-Rapier, Ltd. The company's address is 32, Victoria Street, London, S.W.1.

THE BRITISH RADIO VALVE MANUFACTURERS' ASSOCIATION and the Electronic Valve and Semiconductor Manufacturers' Association have moved to Mappin House, 156–162, Oxford Street, London, W.1 (telephone, Langham 8562).

HOLBROOK MACHINE TOOL COMPANY, Ltd., has announced that, with effect from March 1, the registered offices and administration of the company will be transferred to Cambridge Road, Harlow, Essex (telephone, Harlow 2257).

ELGAR MACHINE TOOL COMPANY, Ltd., has been appointed the exclusive distributor in the United Kingdom for the A.C.E.C. range of transfer machinery manufactured by Ateliers De Constructions Electriques, of Charleroi, Belgium.

STARTRITE ENGINEERING COMPANY, Ltd., Startrite Machine Tool Company, Ltd., and Startrite Sales, Ltd., announce a change of address for all sales inquiries to Darland Hall, Star Mill Lane, Chatham, Kent (telephone, Gillingham 50151/2/3).

TOLIMIT GAUGES, Ltd., 16, Peterborough Road, London, S.W.6, has concluded a long-term agreement with the Van Keuren Company of Massachusetts, U.S.A., under which the two companies are each to sell both Tolimit and Van Keuren products.

MARCONI'S WIRELESS TELEGRAPH COMPANY, Ltd., Chelmsford, Essex, and Hermes Electronics Company, of U.S.A., have concluded an agreement providing for general technical collaboration between the two companies in the field of point-to-point communications.

WOODALL-DUCKHAM CONSTRUCTION COMPANY, Ltd., the principal operating company of the Woodall-Duckham Group, has contracted to purchase the whole of the issued share capital of Ames Crosta Mills and Co., Ltd., of Heywood, Lancashire. Ames Crosta Mills and Co., Ltd., will continue to operate as an independent unit under its present board of directors within the Woodall-Duckham Group of Companies.

THE PRESSED STEEL COMPANY, Ltd., announces that it has taken over the aviation interests and operation of the Oxford Airport at Kidlington. The management will comprise Mr. J. W. Gillespie, general manager, and Mr. L. V. Harcourt, aerodrome manager. The company states that it is in no way intended to impose any restrictions on other users of the airport and that it is intended to continue with all aspects of flying at present in operation.

STEWARTS AND LLOYDS, Ltd., has set up a new Pipework Engineering Division, responsible for the making and marketing of all forms of manipulated pipework. This division is served by modern shops at Tollcross, Glasgow, and at Coombs Wood, near Birmingham, and it is under the chairmanship of Mr. James Carson and Sir Alan Eliott Lockhart as managing director; Mr. G. T. T. Rheam, general manager for sales and engineering, and Mr. A. H. Kynaston, general manager for production. The offices of the division are at Broad Street Chambers, Birmingham, 1, and 41, Oswald Street, Glasgow, C.1.

ALEXANDER STEPHEN AND SONS, Ltd., Linthouse, Govan, Glasgow, and de Laval Ljungstrom Turbine Company, Stockholm, Sweden, have signed an agreement granting to Alexander Stephen and Sons, Ltd., an exclusive right and licence to manufacture in Scotland de Laval marine steam turbine main propulsion units with an output exceeding 6000 s.h.p., and a non-exclusive right and licence to sell such main propulsion units manufactured by them for installation on board ships being built, converted or repaired at shipyards in the United Kingdom and British Commonwealth except Canada, and for installation on board ships being built, converted or repaired for British owners in all countries except U.S.A., Canada, Mexico, Philippines and Sweden.

HAYWARD TYLER AND CO., Ltd., a member of the Stone-Platt Group, states that its licence from the de Laval Steam Turbine Company of Stockholm to manufacture its steam turbines up to 6000 h.p. is still effective.

Contracts

HEENAN AND FROUDE, Ltd., Worcester, has received from Rolls-Royce, Ltd., an order for a plant to test jet engines up to 25,000 lb forward and 11,000 lb reverse thrust. It will be supplied with two special engine transporters, either of which will fit on to the cradle of the thrust measurement plant to act as a quick change engine mounting.

THE CONTINUOUS CASTING COMPANY, Ltd., is to install the continuous casting plant included in the latest development programme of The Steel Company of Wales, Ltd. The B.I.S.R.A. process is to be used and the plant will be a twin-strand unit, capable of producing slabs from 27in by 6in to 48in by 9in and up to 21ft in length from basic Bessemer steel.

A.E.I., Ltd. (Heavy Plant Division) has received an order worth more than £200,000 for germanium rectifiers for a third tinning line at the Steel Company of Wales' Trostre Works, Llanelly. The equipment, which will consist of five large groups of rectifiers, will be used for the cleaning, pickling, tinning and chemical treatment of strip in a range of widths from 27in to 38in, and thicknesses from 0·006in to 0·015in. The total capacity of the installation will be about 4000kW and the total current more than 200,000A at voltages up to 24V. The two largest groups of rectifiers will be used for the tinning operation. Saturable reactors will provide independent control of the output of the rectifiers to each side of the strip. As tinplate for canning needs a heavier coating on one side (the inside of the can) than the other, the output of the rectifiers is adjusted accordingly. Air cooling is used, heat exchangers supplying cooled air to the germanium cells in an enclosed forced-ventilation system. McLellan and Partners are the consulting engineers.

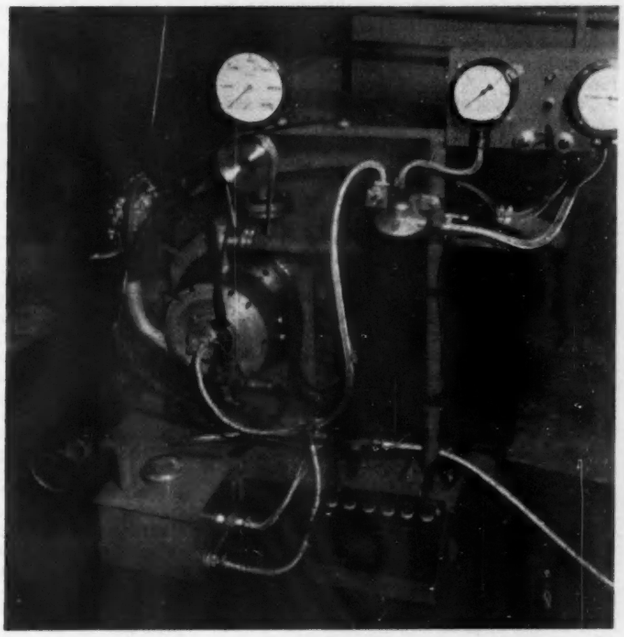
A.E.I., Ltd. (Turbine Generator Division), has received an order, worth about £2,000,000, from Atomic Energy of Canada, Ltd., for a 220MW steam turbine-generator for the nuclear power project at Douglas Point on tne eastern shore of Lake Huron. Certain parts will be made in Canada. The machine will be a two-cylinder 1800 r.p.m. set taking saturated steam with turbine stop valve conditions of 565 lb per square inch gauge, 482 deg. Fah. After expansion through h.p. stages in the first cylinder, the steam will pass through external water separators, then a live-steam reheater (raising its temperature to 430 deg. Fah.) and then to the three-flow low-pressure section of the turbine. One l.p. flow will be contained in the first cylinder; the other two will form a double-flow section, in the second cylinder. Each flow will terminate in a Baumann multi-exhaust stage, from which the steam will enter the condenser at a vacuum of 1in Hg Abs. The direct-coupled generator will supply 60 c/s alternating current at 18kV, 0·9 p.f., and will have water-cooled stator windings, in conjunction with a hydrogen cooling system operating at a gas pressure of 30 lb per square inch gauge. It will also be capable of operation as a synchronous condenser.

CONTINENTAL AFFAIRS

by Our Continental Editor

Rotary Piston Engine Symposium

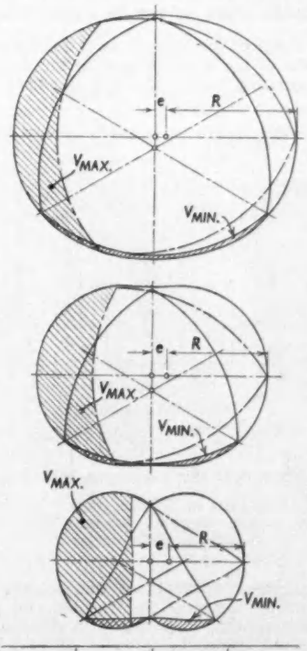
Last month there was convened in Munich by the Verein Deutscher Institute a symposium devoted to the state of the art in rotary positive-displacement internal combustion engines. At the time of the meeting the newly developed N.S.U.-Wankel engine was seen running on the test bed; this engine has already been installed and utilised in a "Sport Prinz" two-seater car.



A LARGE audience, numbering about 1500 people, had followed the invitation of the Verein Deutscher Ingenieure to receive at the Congress Hall of the Deutsches Museum at Munich on January 19, an account on the present stage of development of internal combustion engines having a non-reciprocating piston travel. In spite of the rather generalised description of the subject matter to be discussed, it was clear that this symposium would preferably, if not entirely, deal with the new N.S.U.-Wankel engine which, publicly announced about two months ago, has received a great deal of wanted and unwanted publicity, and has raised among experts a certain amount of scepticism.

The expectation that at this meeting some authorised information on the work in progress would be released proved to be accurate; five papers, all read by technologists who were actively engaged in various stages of the development of the N.S.U. engine, dealt with such aspects as the history, the thermodynamic and kinematic principles, the constructional layout of the experimental engines and with the test results so far achieved. An engine was demonstrated on the test bed, and a small circle of industrialists, university professors and representatives of the technical press was given the opportunity of examining in detail the principal parts of an engine.

After an introductory paper, read by the noted thermodynamicist, Professor E. Schmidt of Munich Technical University, dealing with the history and with the working cycle of the engine, Professor O. Baier of Stuttgart T.U., reported on his work in establishing the optimum kinematic conditions for the shape of the casing and the rotor; he also gave information how these parts can be economically produced in a special form-generating grinding machine. Herr F. Wankel, the inventor of the engine, gave a comprehensive account of the history of rotary piston machines; he pointed out that such machines, while quite satisfactory as pumps and compressors, proved to be unsuitable as prime movers when subjected to the high pressures and temperatures of the working medium. He maintained that his early research work on rotary valves, dating back to 1930, and pursued until the end of the last war at the German Aeronautical Research Institute, had greatly assisted him in overcoming the difficult sealing problems connected with his engine.



	ϕ	R/e	ε_{max}
Top	15 deg.	11·5	30
Middle ...	25 deg.	7·1	18
Bottom ...	50 deg.	3·9	10

Fig. 1—Two-node epitrochoid with inner envelope. The size of the casing varies, at a given chamber volume, with the shape of the curves

Dr. E. W. Huber, a lecturer of Munich T.U., in his paper on "The Thermodynamic Investigation of an Epicyclic Piston Engine," reported on an extensive experimental programme, carried out on behalf of the N.S.U. Company in his own independent research institute mainly for the purpose of establishing the potential merit of the new engine in comparison with orthodox piston engines. His conclusions were underlined and supplemented by Dr. W. Froede, chief research engineer of the N.S.U. factory, who released some interesting information on the constructional layout of the experimental engines, and on the results of tests conducted in the firm's own research department.

In consequence of the information now available it is possible to form not only a fairly clear idea about the design and the working principle of the engine, but also to a certain extent to assess its value, its limitations and its potential impact on future engine design.

In view of the fact that the principle and the general layout of the N.S.U.-Wankel engine has already been described in THE ENGINEER of December 18, 1959, it is not intended to enlarge upon this description, which was based on preliminary press releases, but mainly to add such new facts as emerged from the essence of the papers read at the V.D.I. meeting and from such information as could be obtained by examining the engine and its main parts.

KINEMATICS AND GEOMETRY OF THE TROCHOID

In our previous publication on the N.S.U. engine reference has been made to the fact that the casing has the form of a two-node epitrochoid. It will be remembered that an epitrochoid is one of the numerous varieties of epicyclic curves and represents the path traced by a point on the radius of a circle, rolling without sliding on the outer circumference of

CONTINENTAL AFFAIRS *(Continued)*

another fixed circle; the hypotrochoid is generated in a similar way by a point on the radius of a circle, rolling on the inner circumference of a fixed circle. If an epitrochoid or a hypotrochoid is rotating about an axis, and another appropriate body, representing either the inner or the outer envelope of the trochoid, rotates on another parallel axis in the same direction, but with a different angular velocity, then spaces are formed between the trochoid and the envelope the area of which varies between a minimum and a maximum according to a sine function.

This property of trochoidal curves has been known for more than 100 years, and several patents, the first one probably filed as early as 1879, suggested the possibility of utilising the phenomenon in rotary positive-displacement machines such as pumps and compressors. The idea of applying the working principle of such machines to internal combustion engines was suggested in 1938 by De la Vaud, who in his French patent No. 853,807 described several examples of engines, based on the conception of a hypotrochoid rotating in combination with its inner envelope. The use of a two-node epitrochoid casing and an inner three-lobed body, the latter rotating at a 2 : 3 speed ratio relative to the former, was first investigated by Felix Wankel. The engines built by him, first at his own development laboratory and later on in association with the N.S.U. Company, were indeed based on such a design, and when initially tested in 1956, gave promising results.

In the course of further development it was established that Wankel's aim, of materialising the four-stroke cycle of an internal combustion engine in a rotary positive-displacement machine, could equally well be achieved by a considerably simpler design, namely by the kinematic inversion of the original arrangement. In the new Wankel engine, now exclusively built, the two-node epitrochoid casing has been maintained, but it is kept stationary. The inner member is basically an equilateral triangle and, in order to satisfy the conditions of an inner envelope of the epitrochoid, it has arc-shaped sides. The radius of these arcs is selected so that the overall distance between the apex of the triangle and the arc is equal to the short axis of the trochoid, namely 2 (R-e), so that at t.d.c. and b.d.c. i.e. when the centre of the rotor passes through the short axis, the apex as well as the arc maintain contact with the trochoid, thereby temporarily subdividing the casing into two symmetrical parts.

The rotor, besides rotating about its own symmetrical axis, orbits about a fixed point constituting the centre of symmetry of the casing, i.e. the intersection of the long and of the short axis of the trochoid. The apices of the triangular rotor, spaced at 120 deg. relative to one another, while sliding on the curved path of the trochoid, maintain a continuous contact with the latter during their orbit; crescent-shaped cells or chambers of variable volume are formed between casing and rotor in which the individual stages of the four-stroke cycle take place successively.

It has been stated that in the first Wankel engines, with rotor and casing both rotating in the same direction, the speed ratio of these two parts was 2 : 3, resulting in a velocity of the rotor relative to the casing of 1/3. The same relative velocity between rotor and casing is maintained in the new engines with a planetary (epicyclic) motion of the rotor; in order to satisfy these conditions (which are intrinsically based on the geometry of trochoid) an ingenious design has been adopted. While the rotor revolves bodily about the mathematical "fixed point," in this case the centre of symmetry of the casing, it also rotates about its own axis (eccentric to that of the main axis), but in opposite direction and with an angular velocity of 2/3 of the main axis. A positive angular displacement of 90 deg. of the latter corresponds to a 60 deg. negative angular displacement of the rotor relative to its own axis. The positive angular velocity of the rotor relative to the main axis, therefore, is only 30 deg., i.e. three revolutions of the main shaft correspond to one revolution of the rotor. The correct ratio of the two angular velocities is effected by a reduction gearing, comprising an internally geared annulus attached to the rotor and a fixed externally geared reaction member located at one side cover of the casing, coaxially with the main shaft.

The rotor, while turning about its own axis, is not subject to any torque imposed by the gas forces as the resultant of these forces passes through the symmetrical axis. A comparatively small torque, however, is transmitted to the rotor by the previously mentioned reduction gearing which controls its angular velocity in relation to that of the drive shaft. As the centre of the rotor bearing coincides with the centre of gravity, the rotor is balanced relative to its own axis. Centrifugal forces, of constant magnitude (disregarding such forces caused by the periodical shifting of the centre of gravity of the rotor caused by the swirling motion of the cooling oil inside the latter) act upon the rotor bearing and on the main bearings of the drive shaft; the latter can be fully balanced by appropriate rotary balance weights. In absence of any reciprocating masses there are no inertia forces which might cause unwanted vibrations.

For want of a generally accepted nomenclature machines with a rotating casing and a rotating inner body have been referred to as "rotary piston engines," and those with an orbiting rotor as "planetary or epicyclic piston engines." Both terms might be misleading, and, for reasons of clarity, the designations further used in this report are the abbreviations preferred by the inventor and by the N.S.U. Company, namely, D.K.M. (Dreh-Kolben Motor) for the old (now discontinued) engine, and K.K.M. (Kreis-Kolben Motor) for the latest design.

Optimum Shape of the Trochoid Casing

The shape of the epitrochoid is determined by the ratio of the eccentricity e to the length of the generating radius R. Fig. 1 shows how,

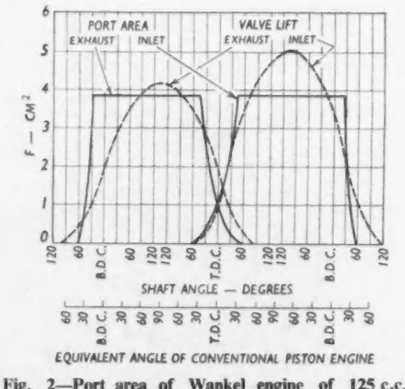


Fig. 2—Port area of Wankel engine of 125 c.c. chamber volume compared to valve lift diagram of 125 c.c. piston engine

for the given volume V_c of one chamber, the size and the shape of the trochoid casing can vary considerably. For the ratio $R/e=\infty$ it is obviously a circle, for a ratio of 11·5 : 1 it resembles an elliptic, while for smaller ratios the curve has two indents in its small axis which, as Fig. 1 shows, are rather small at the ratio $R/e=7{\cdot}1$ but very pronounced at the ratio $R/e=3{\cdot}9$. The R/e ratio also determines the maximum angle of obliquity, ϕ, which the generating radius forms with the normal to the curvature. For reasons to be discussed later on it is advisable to keep this angle fairly small to facilitate the sealing between the apex of the rotor and the path of the casing. The maximum deviation of ϕ from the normal should not exceed ± 30 deg. which corresponds to an R/e ratio of something between 6 and 7. Fig. 1 also shows the influence of the R/e ratio on the variation of the area F of each individual cell during the rotation of the rotor and, thus, on the theoretical compression ratio ε. It will be seen that an engine with a big R/e ratio, i.e. with a small angle of obliquity, requires a bigger casing, but is superior to a machine with a small R/e ratio with respect to the maximum obtainable compression ratio. The maximum theoretical compression ratio of a spark-ignition engine having an angle of obliquity of 30 deg. is 15·5 : 1, a ratio which leaves enough margin for accommodating in the arc-shaped sides of the rotor recesses for a clearance volume amounting to about 50–100 per cent of the theoretical compression space. This clearance space is required not only for producing a well-formed combustion space of favourable anti-knock properties, but also for the purpose of providing a sufficiently wide area to permit the gases at t.d.c. to flow through the restricted passage of the waisted part of the casing without excessive throttle losses.

It is clear that each part of the cycle which comprises a change from the minimum volume of one chamber to its maximum value corresponds to a turning of the drive shaft of 270 deg., in contrast to the orthodox piston engine where it corresponds to 180 deg. The K.K.M. engine, where in the course of one revolution of the rotor the volume of each chamber is successively induced, compressed, burnt and exhausted, can be regarded, with respect to its chamber capacity, as a two-stroke engine, though the cycle itself is clearly that of a four-stroke engine. It follows that for the purpose of determining the output of the engine in terms of the speed of the drive shaft, the orthodox formula relating to two-stroke engines can be used. If V_c represents the swept volume of one chamber in litres (dm^3), n_s the rotational speed of the output shaft in revolutions per minute, and p_{me} the brake mean effective pressure in kilogrammes per square centimetre, then the effective output N_e in metric horsepower amounts to :

$$N_e=\frac{3V_c \cdot p_{me}}{450} \cdot \frac{n_s}{3}$$

which is equivalent to that of a three-cylinder two-stroke engine of a capacity of V_c litre per cylinder, transmitting its torque to the drive shaft at a step-up ratio of 3 : 1. When simplifying the above formula to :

$$N_e=\frac{V_c \cdot p_{me}}{450} \cdot n_s$$

it is apparent that the output and, consequently, the cyclic irregularities of a Wankel engine of V_c chamber capacity are comparable to those of a single-cylinder two-stroke engine of V_c cylinder capacity. In comparison with the latter engine, however, the brake mean effective pressure of the Wankel engine, employing the four-stroke cycle, is at least 50 per cent higher. The high brake mean effective pressure and the high output speed together account for the small bulk and weight of the Wankel engine; on the other hand they indicate that the engine is subject to considerable thermal loading.

There is another aspect in which the K.K.M. engine resembles a two-stroke engine, namely, in respect of the control of the gas exchange. Inlet and exhaust ports, arranged in the circumference of the casing, are covered or uncovered, respectively, by the three radial sealing elements of the rotor. It is obvious that ports of adequate dimensions offer larger and less restricted flow areas than valves, so that—in absence of the turbulence caused by valve plates and valve stems—the effective gas exchange area is decidedly favourable; further, the steep rise and the rapid closure of the ports permits a

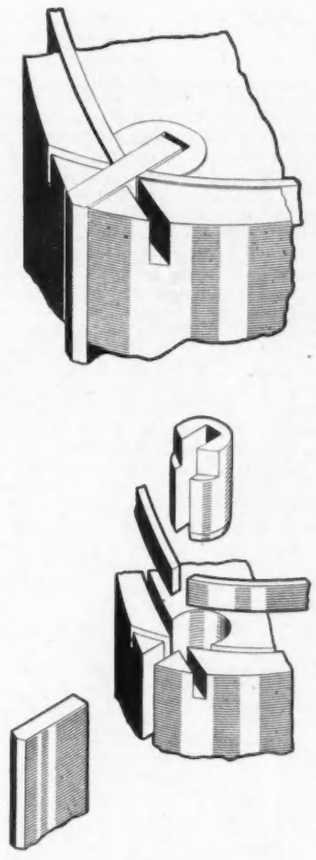


Fig. 3—Radial and axial sealing of the rotor, comprising sliding vanes at the apices and ring segments at the side faces

shortening of the timing angle. These conditions are shown in Fig. 2, presenting a comparison between the port opening area of a K.K.M. engine of 125 c.c. chamber capacity, and the valve lift diagram of a 125 c.c. air cooled N.S.U. motor-cycle engine, both running at 12,000 r.p.m. In this connection it should be mentioned that, in order to obtain comparable data for the gas exchange, the speed of the K.K.M. engine has been based on the " thermodynamic speed," i.e. on a speed of two-thirds of the shaft speed, to allow for the difference between the 270 deg. " stroke " of the rotary engine compared to the 180 deg. stroke of the orthodox engine. The steep rise of the port opening curve permits the utilisation of the pressure at the end of the expansion period to the fullest extent, while the rapid closure offers the possibility of making use of the " dynamic supercharging " effect.

Reference has already been made to the fact that, for practical reasons, the development of the D.K.M. engine has been discontinued in favour of the K.K.M. engine. It is considerably easier to employ a stationary casing instead of a rotary one, thus facilitating the cooling, the lubrication and the arrangement of the sparking plug.

On the other hand, the K.K.M. engine has certain disadvantages : the out-of-balance masses of the eccentric and of the rotor have to be compensated for by two equivalent rotary masses arranged on the drive shaft on either side of the eccentric. Further, the centrifugal forces, caused by the rotor orbiting about the axis of the drive shaft, impose additional stresses upon the rotor bearing which is already heavily loaded by thermal stresses. There are also certain difficulties concerning the circulation of the cooling medium through the rotor. If, for reasons of a compact and economical design, a casing with a small R/e ratio, i.e. a trochoid with substantial indents, is preferred, the conditions of maintaining at these points an effective contact between the sealing elements of the rotor and the casing are not favourable.

Sealing Elements

From the very beginning of the development of the N.S.U. engine it was apparent that the sealing of the rotor relative to the casing was a considerable problem. Great difficulties had to be overcome to obtain a gas-tight radial seal at the three apices of the triangular rotor. It is obvious that any seal between the apex and the wall can maintain only line contact because of the periodical change in amplitude and direction of the contact pressure and of the variation of the angle of obliquity. On the other hand, the variation of this angle over the whole path of each sealing strip helps to keep the wear of the radiused tip within reasonable limits as the line of contact shifts over the total width of the vane.

The vanes are pushed towards the curved surface of the casing by the centrifugal forces which, at the apices of the rotor, vary in magnitude and direction ; other forces determining the contact pressure are gas forces, friction and Coriolis forces. Reference has already been made to the fact that the vanes, when sliding over the nodes of the trochoid tend to lose temporarily contact with the wall. Although centrifugal forces and gas pressures quickly restore the original position of the vanes, it is possible (and has indeed occurred in several test engines) that this phenomenon might lead to an oscillating motion of the vane similar to the well-known piston ring " flutter," and result in pitting the trochoid path. Expander springs, located in the main groove, and chromium plating of the path (for the purpose of reducing the coefficient of friction) have been found useful in overcoming these difficulties.

The elements, sealing the side faces of the rotor relative to the plane inner surfaces of the end covers, are basically arc-shaped segments of piston rings, placed in grooves which closely follow the outer contour of the rotor arcs ; they are pushed towards the sides of the end covers by expander springs located at the bottom of the ring grooves. The ring segments, three for each rotor facing, join with the radial sealing vanes by means of a device shown in Fig. 3. It consists of a cylindrical member of 7mm–10mm diameter and about 20mm long which is positioned near each apex on either side of the rotor. This cylinder is longitudinally slotted to accommodate the innermost part of the sliding vane ; it has two further recesses to locate the ends of two adjacent segment rings, thus establishing a complete gas-tight sealing along the whole contour of the rotor.

It is not known whether the arrangement illustrated in Fig. 3 is the latest sealing device developed by N.S.U., but it is one of the numerous versions which have been successfully tried within the last two years. In the course of this development work, various materials have been tested for their suitability as sealing elements ; among them steel, light metal, bronze, spheroidal-graphite iron and cast iron. The best results were obtained with the special high-duty cast iron commercially used in the manufacture of piston rings.

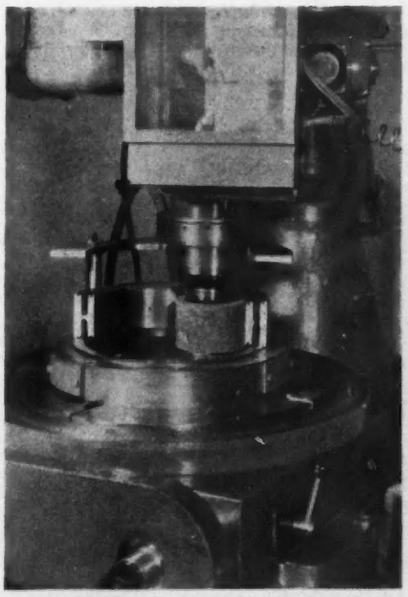


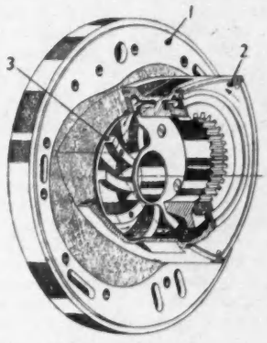
Fig. 4—Machining of the casing on a copying grinding machine (master cam and casing are sectioned)

Machining of the Trochoidal Casing

The trochoid casing, if made of cast iron, is machined by grinding in order to obtain the required surface finish of the path. It would be quite feasible to grind the trochoid by means of a form-generating machine, but it has been found more practical to use the generating process only for the grinding of a master cam and to produce the casing on a copying grinding machine. Fig. 4 shows such a copying grinder with the master cam and the casing in sectioned presentation. During the grinding the spindle of the machine oscillates in the axial direction in order to obtain an optimum surface finish.

Aluminium casings are machined to a very fine finish on a copying milling machine, then plated with a 0·40mm layer of non-porous chromium, and eventually ground on a copying grinding machine. In this connection it should be mentioned that most of the latest experimental engines have been fitted with such casings which combine the advantages of the hard, wear-resisting chromium-plated path with the high thermal conductivity of aluminium.

So far all the experimental engines made by N.S.U. and Curtiss-Wright have been equipped with liquid cooling. As the specific temperature



(1) Side cover of casing.
(2) Rotor.
(3) Scoop vanes.

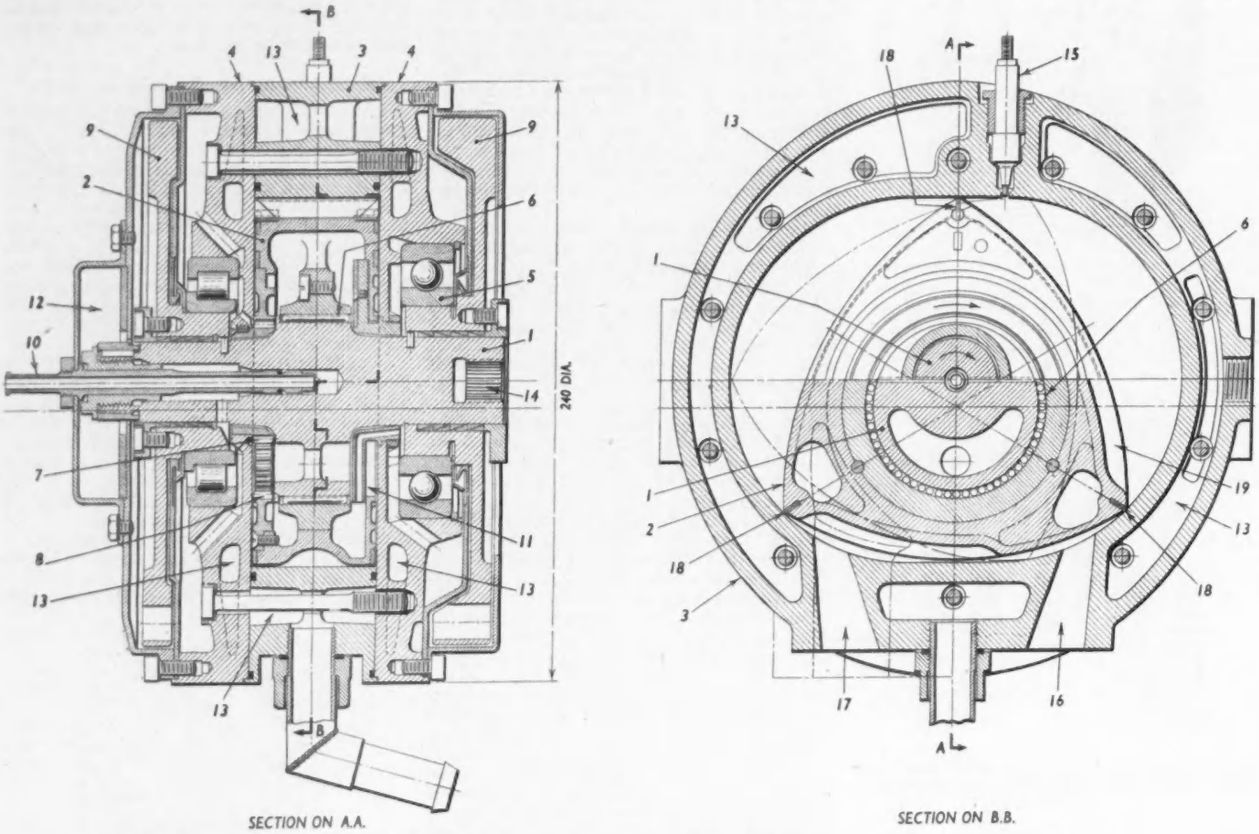
Fig. 5—Vaned scoop attached to the front side cover effecting the return of the cooling oil from the inside of the rotor to the reservoir

stresses are considerably higher than those of comparable conventional engines, a controlled flow of the coolant is essential. Water is used for cooling the casing and the end covers, and the passages of the cooling jackets are so dimensioned that the velocity of the circulating coolant has its maximum round the thermally highly stressed zones around the sparking plug and the exhaust port. The rotor of the engine, now preferably cast of colloidal-graphite iron, is thermally less stressed than the casing. It is cooled by oil for reasons of sealing the rotor bearing relative to the coolant. The oil volume inside the rotor is subject to considerable churning due to the periodical variation of the peripheral velocity of the apices, and extensive experimental work was required to devise means for an effectively controlled oil circulation (Fig. 5). Lubricating oil is fed into the rotor through the front end of the hollow drive shaft and is returned to the reservoir or to the oil cooler by means of stationary vanes, arranged at the rear side cover and protruding into the cavity of the rotor. This procedure is essential as an excessive volume of oil, being subject to violent agitation, seems to have a detrimental effect on the mechanical efficiency of the engine.

Constructional Details of the Experimental Engines

The principal experimental engines, built in several versions between 1957 and 1959, com-

CONTINENTAL AFFAIRS *(Continued)*



1—Eccentric shaft.
2—Rotor.
3—Casing.
4—Side covers of casing.
5—Main shaft bearings.
6—Rotor bearing.
7—Gear wheel located in side cover.
8—Geared annulus attached to rotor.
9—Flywheels.
10—Lubricating oil pipe.
11—Cooling oil scoop.
12—Space for electric contact breaker.
13—Water jacket.
14—Splined joint to output shaft.
15—Sparking plug.
16—Exhaust duct.
17—Inlet duct.
18—Radial seals.
19—Combustion recess in rotor.

Fig. 6—Longitudinal and cross section of type K.K.M. 250

prise rotary piston engines (type D.K.M.) of 125 c.c. chamber volume and epicyclic piston engines (type K.K.M.) of 125 c.c. and 250 c.c. chamber volume. Apart from the now obsolete type D.K.M., two versions of the type K.K.M. 125 were built and tested, one with ball and roller bearings for the main bearings and the rotor bearing, the other with plain bearings all round. The dry weight of this engine without accessories was 17 kg with cast iron casing and 11 kg with light-metal casing. Water cooling was employed for the casing and for the end covers, and lubricating oil cooling for the rotor. The trochoid path was nitrided in case of the cast iron or spheroidal-iron version and chromium-plated in the case of the light-metal design. The rotor was alternatively made of an Al-Si alloy or of welded steel plate, the latter design proving to be the better solution.

The type K.K.M. 250 is basically similar to the smaller design, but has a greater R/e ratio to allow the investigation of combustion chambers of different size and shape. It will be seen from Fig. 6, showing the longitudinal and cross-section of the engine, that the drive shaft is made integral with the amply dimensioned eccentric and is carried in a roller bearing at the free end, and in a ball bearing at the output end. The rotor shown in Fig. 6 has a needle bearing which, however, has been replaced in later experimental machines by a quadruplex roller bearing. Counter-weighted flywheels on either side of the rotor reduce the speed fluctuations of the shaft and balance the centrifugal loadings on the main bearings imposed by the rotor and its oil contents. Both flywheels are shielded by disc plates and labyrinth seals against oil spray, and scraper rings on the side facings of the rotor prevent the entrance of oil into the working chambers of the engine. The rotor of the type K.K.M. 250 is shown in Fig. 7.

The dry weight of the engine without accessories is 33 kg with cast iron casing, and 22 kg with light-metal casing, equivalent to a specific weight of the engine with accessories of probably less than 1·5 kg per horsepower.

Test Results

Extensive tests were carried out both by the N.S.U. development department and by Dr. Huber's Research Laboratory, to assess the performance and the general behaviour of the Wankel engine in comparison with conventional piston engines of equivalent cylinder volume. The piston engines were single-cylinder air-cooled N.S.U. motor-cycle engines of 125 c.c. and 250 c.c. capacity, representing in their particular field the latest stage of development.

Fig. 8 shows the results of one of the tests conducted to compare the volumetric efficiency and the frictional losses of the two Wankel engines, K.K.M. 125 and K.K.M. 250, with those of a conventional 125 c.c. piston engine. For reasons of comparison the speed of the

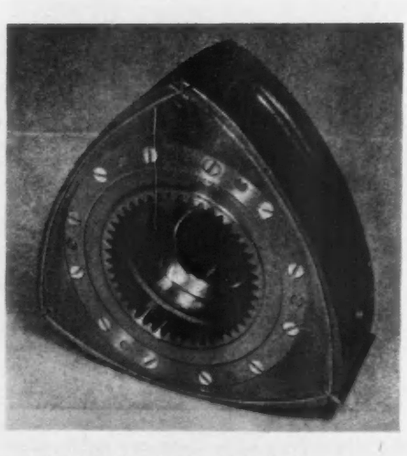
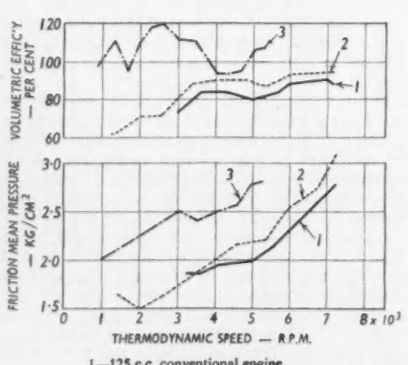


Fig. 7—Rotor of type K.K.M. 250 engine



1—125 c.c. conventional engine.
2—125 c.c. K.K.M. engine.
3—250 c.c. K.K.M. engine.

Fig. 8—Volumetric efficiency and friction mean pressure of motored engines

Wankel engines were based on the previously mentioned "thermodynamic speed," equivalent to two-thirds of the shaft speed. Fig. 8 shows that, in spite of the smaller number of moving paths, the Wankel engine in its present stage of development has a higher friction mean pressure, i.e. a lower mechanical efficiency than the piston engine. On the other hand the volumetric efficiency is higher, especially that of K.K.M. 250, because of the smaller throttle losses at the inlet which permits a dynamic charging of up to 120 per cent. The volumetric efficiency is quite satisfactory even at the low speed of about 1000 r.p.m. which seems to indicate that the sealing arrangements are quite effective.

Brake tests with all the above-mentioned engines were carried out at compression ratios ranging from 7·5 : 1 to 8 : 1, and brake mean effective pressures from 9·8–10·5 kg per square centimetre were obtained. Fig. 9 presents test results of the K.K.M. 250 engine showing the high volumetric efficiency (about 105 per cent at 8500 r.p.m.), and favourable mean effective pressures in the speed range between 2000 and 9000 r.p.m. The optimum fuel consumption of 250 gramme per horsepower hour at 7500 r.p.m. is likely to be reduced in the course of further development.

An exact assessment of the thermodynamic

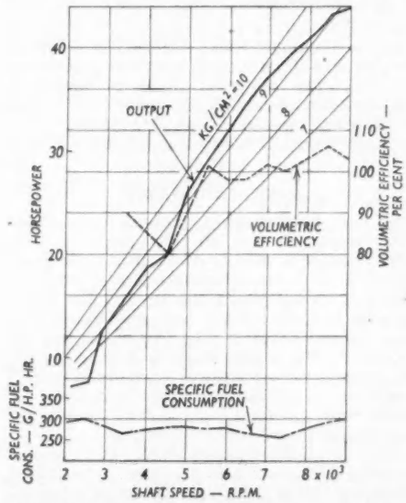
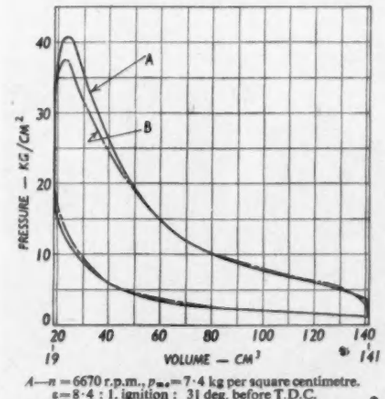


Fig. 9—Output, volumetric efficiency and fuel consumption of type K.K.M. 250

behaviour of the earlier D.K.M. 125 engines was not possible because of the difficulty of obtaining accurate indicator diagrams from the rotating casing. K.K.M. engines, however, could be properly examined with a cathode ray oscillograph, the pick-ups of which were suitably arranged at four points at the circumference of the casing. A comparison between the pV diagrams of a K.K.M. 125 engine and that of the 125 c.c. conventional piston engine (Fig. 10) shows that the difference between these



A—n = 6670 r.p.m., p_{me} = 7·4 kg per square centimetre.
ε = 8·4 : 1, ignition : 31 deg. before T.D.C.
B—n = 9470 r.p.m., p_{me} = 7·2 kg per square centimetre.
ε = 9·6 . 1, ignition : 38 deg. before T.D.C.

Fig. 10—Pressure-volume diagrams of 125 c.c. four-stroke piston engine and of type K.K.M. 125

two engines in respect to the compression, the rate of pressure rise, and the expansion is very small. Such a positive result is actually surprising because one would expect the combustion process of the Wankel engine to be negatively affected by the increased rate of heat transfer of the gas flowing along the large cooled areas of the casing at considerable velocity.

The fact that excessive heat losses and leakage losses are not discernible in the pV diagram nor in the more accurate log p log V diagram, gives reason to believe that the new engine in thermodynamical respect is just as efficient as the conventional engine. Considering that the Wankel engine, after about three or four years'

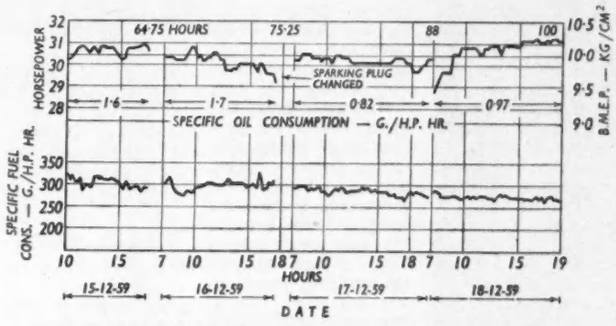


Fig. 11—Part of 100 hours endurance test of type K.K.M. 250

research work, is still in the early stages of its development—compared to the highly refined piston engine of to-day—such a result is most encouraging.

It is stated that during the first stages of the research programme more emphasis was laid on attaining satisfactory results in respect of specific output and fuel consumption than on optimum wear resistance. Results so far available are based on endurance tests extending over a period of 100 hours only and are not entirely conclusive. A K.K.M. 250 engine was subjected to such a test in July, 1959, and run without any defects developing 21 h.p. at 4700 r.p.m. The engine maintained its full output until the end of the test and, after cleaning and removal of the carbon deposits, was used again for another endurance test.

An improved version of the K.K.M. 250 engine was also tested for 100 hours in December, 1959, this time mainly for the purpose of determining the wear properties of a chromium-plated light-metal casing in conjunction with a cast iron rotor. The engine was run at full load and developed 31 h.p. at 5500 r.p.m., equivalent to a brake mean effective pressure of about 10 kg per square centimetre. Fig. 11 shows the performance and the fuel consumption of the engine during part of this test ; it will be seen that after the initial running-in period the specific consumption of the lubricating oil became gradually lower.

Measurements taken after the 100-hour runs showed that the wear of the radial vanes varied between 0·06mm and 0·11mm, and that of the ring segments of the rotor faces between 0·01mm and 0·02mm. The wear of the trochoid path was generally satisfactory with the exception of the thermally and mechanically (vane flutter) highly stressed indents close to the sparking plug and in the neighbourhood of the exhaust port where, after fifty hours, erosive wear amounting up to 0·05mm could be observed. Improved surface finish, chromium-plated aluminium casings and protective layers of metallic molybdenum, sprayed on the most exposed parts of the trochoidal path, have been successfully tested. It is confidently believed that by such means the wear resistance of the casing can be improved to such an extent, that for at least 500 hours of full-load operation the overall performance of the engine would not be adversely affected. The main bearings and the rotor bearing can easily be dimensioned for adequate wear resistance.

Prospective View of Further Development

At present it is not possible to give any definite prognosis about the future development of rotary and epicyclic piston engines and their potential field of application. Test results so far achieved with experimental engines undoubtedly can and will be improved. Little is known about the behaviour of engines of different chamber volume ; it can only be stated with certainty that, for chamber volumes ranging from 125 c.c. to 1000 c.c., satisfactory operation at mean effective pressures of more than 9 kg per square centimetre have been achieved. It is expected that in engines of bigger chamber volume the problem of sealing will prove less difficult, and, further, that the fuel consumption will be lower. The American Curtiss-Wright Corporation which has acquired the licence of the N.S.U.-Wankel engine is reported to have operated an engine of 1 litre chamber volume for several hundred hours without observing any output-reducing wear. The average fuel consumption in these tests amounted to 200 grammes per horsepower hour, and it is expected that bigger engines of something between 3 and 10 litres chamber capacity will give even better results.

Engines of larger output can be built in multi-unit arrangement, i.e. by joining two or more standard units in line, the individual rotors rotating on the eccentrics of one common shaft. In the case of a four-unit in-line engine the eccentrics of the drive shaft would be arranged 90 deg. apart, thus eliminating the need for balancing the centrifugal forces imposed by the individual rotors. The free couples, produced in multiple-unit engines having less than six rotors (apart from a four-unit engine with the eccentrics arranged 180 deg. apart), have to be balanced in the orthodox way, i.e. by appropriate weights attached to the drive shaft.

There is a possibility that the K.K.M. engine might be developed to a compound engine of high overall efficiency if the energy of the combustion is expended in two successive chambers of a three-node epitrochoid casing (Fig. 12). The combination of a trochoid supercharger and a K.K.M. engine also seems to be a feasible proposition.

The Wankel engine, so far, has been constructed as an Otto engine, but there are no fundamental reasons which would exclude its conversion into a diesel engine, providing that the ratio of the two main axes of the trochoid is laid out so that a sufficiently high compression ratio can be realised. It will be remembered that the maximum obtainable compression ratio is determined by the R/e ratio ; it should be quite possible to attain effective compression ratios up to about 20 : 1 with a R/e ratio of about 12, but at the expense of a considerable increase of the overall dimensions of the engine. At the present stage of the development it seems rather premature to make any predictions

Fig. 12—Three-node trochoid with four-point rotor

about the economic limits imposed by these conditions or about the question whether or not the elongated combustion space of the Wankel engine will suit the specific requirements of the Diesel process.

Claims have been made in recent press releases that the engine will be insensitive to fuels of widely different character; although it has been reported that preliminary tests with 30-octane petrol proved successful, such statements should be accepted with certain reservations.

Whether or not the Wankel engine, as has

CONTINENTAL AFFAIRS *(Continued)*

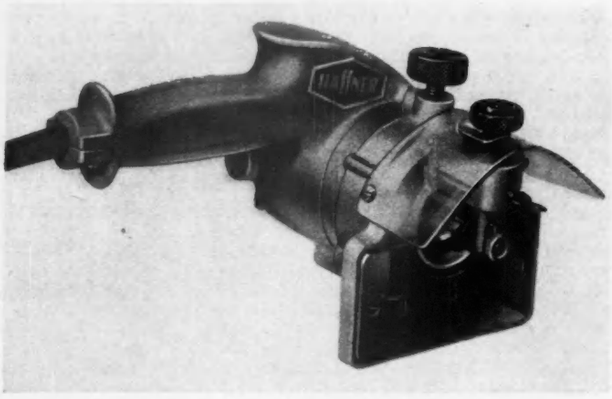
been predicted, will eventually turn out to be "a milestone of revolutionary significance" in the development of the internal combustion engine remains to be seen. There is no doubt that after a comparatively short period of painstaking research and development, remarkable and most promising results have been achieved. On the other hand it must be emphasised that the engine is still in the early stages of its development, and that some time will elapse until it can be considered a marketable proposition. An extensive development programme has been drawn up by the N.S.U. Company and the Curtiss-Wright Corporation; starting with an investigation of engines of different chamber capacity, operating at constant load and constant speed conditions, it is intended to build some medium-sized boat and aircraft engines, i.e. engines with a co-ordinated speed-to-load ratio. The development of automotive engines, operating at variable load over a wide speed range, is believed to offer considerable difficulties but, on the other hand, the greatest commercial reward. The undisputed advantages of the Wankel engine, the small bulk, the favourable power-to-weight ratio, freedom from vibrations, and simplicity of design, should fully justify the great effort which has been made and the intensive development work which is still required.

Bar Cut-Off Machines

A range of automatic bar cut-off machines recently introduced by Maschinenfabrik Peltzer and Ehlers, Krefeld, West Germany, have capacities from 1in to 2⅜in diameter material. The selling agent in the United Kingdom for these machines is the Rockwell Machine Tool Company, Ltd., Welsh Harp, Edgware Road, London, N.W.2., and the accompanying illustration shows the smallest machine in the range. Designed particularly for the cutting-off of steel bars into lengths for the hot forming of bolts, these machines produce accurate, uniform lengths with flat square faces. Their output depends on the cut-off length, which is infinitely variable up to 36in according to machine size. Round, square, hexagon or rectangular section material can be cut equally well and, providing the shearing capacity of the machine is not exceeded, two bars can be cut simultaneously.

The cut-off and feed mechanisms of the machines are controlled by a compressed air operated clutch and brake, the action of the compressed air operated feed rollers which grip the material being synchronised with the machine cycle. These feed rollers are adjustable, within limits, to the material dimensions, and rollers can be supplied with profiles to suit the material section. Alternatively vee-grooved rollers can be supplied so that two or three sets cover the capacity of the machine. For feeding two bars simultaneously, the upper rollers are provided with a compensating device enabling bars of different limits to be fed at the same speed and thus produce the same cut-off length.

In the machine cycle the material passes from the feed rollers through guide bushes and the open cutter blades until it contacts the electrical control stop which is clamped in position to suit the required cut-off length. Actuating this stop arrests the feed mechanism and starts the shearing action: on completion of this shearing action the feed drive automatically re-engages to commence the next cycle. An ejector located immediately behind the upper cutter blade presses the cut-off bar end downwards to fall clear of the machine. On the smallest machine, illustrated, coiled material up to a wire diameter of ½in can be sheared if required and it has a removable straightener built on to the ingoing side.



Portable router for edge milling, bevelling, grooving and sawing of plastic sheet and aluminium

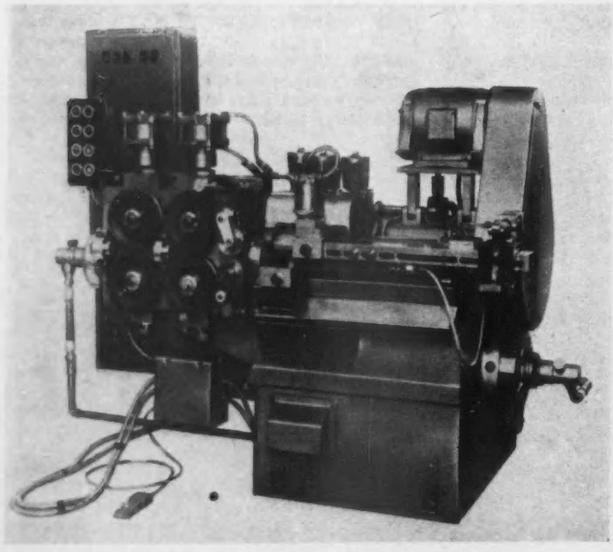
Portable Router

Designed particularly for the machining of plastic sheets, the model "RF-30" router, which we show in the accompanying illustration, can be used to plane the edge of plastic-covered boards with the possibility of combining simultaneously square edge and bevel milling. The required adjustment, it is stated, can be made even while the machine is running. Normally, the cut is controlled by a guide roller which, however, in the case of rough or extremely porous edges (e.g. on fibre boards) can be replaced by a guide shoe. The cutters are equipped with tungsten carbide edges. Changeover to sawing or groove milling in various widths, in plastics or aluminium, can readily be made. The machine is equipped with a 400W universal motor running at 20,000 r.p.m., which is radio-suppressed. The router is made by Gotthold Haffner Maschinenfabrik, Oetisheim, near Mühlacker/Württ (agent: C. D. Monninger, Ltd., St. Anna Works, Overbury Road, London, N.15).

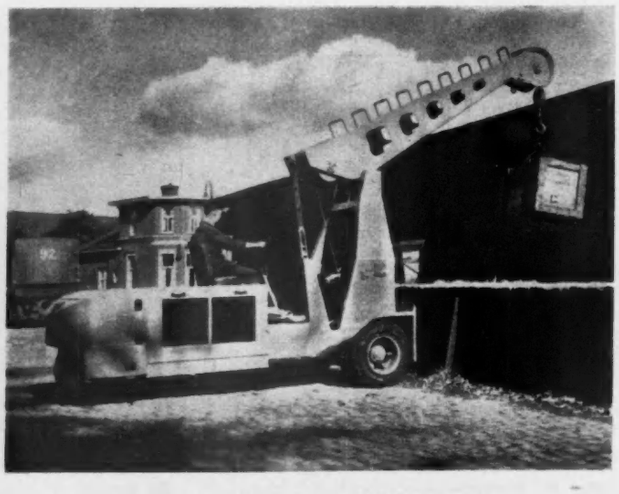
Fork Lift Truck

In the accompanying illustration we show the "Elephant" fork lift truck made by N.V. Maschinefabriek Thole, of Enschede, Holland. This machine can be converted to a crane by fitting a special jib as shown, and for transporting cylinders, rings and pipe material a mandrel can be used. The rear of the truck is provided with a tow hook to handle dollies. If required the front may be equipped with a snow shovel. This versatility is claimed to make the "Elephant" particularly suitable for erection jobs and public works use.

The fork lift truck is fitted with a three-cylinder Perkins P3 diesel engine, developing 23 b.h.p. at 1400 r.p.m. It weighs approximately 5 tons 18 cwt, and has a maximum capacity of 4 tons 9 cwt. Its travelling speed is about 10 m.p.h. and 2½ m.p.h. in reverse, with a turning radius of 24ft 4in. The frame is electrically welded and has box section main girders. Overall length is 33ft 3in and width 7ft 3in on a wheelbase of 12ft 9in. The lifting speed is approximately 16ft per minute for maximum load. There are mechanical service brakes on front axle brake drums and a parking brake on the cardan axle.



Automatic bar cut-off machine for cutting up to ½in diameter material



Fork lift truck convertible into 4½-ton crane

THE AMERICAN SCENE

by Our American Editor

Argonne Fast Source Reactor in Idaho

ANOTHER operating reactor was recently added to the nuclear research facilities at the U.S. Atomic Energy Commission's National Reactor Testing Station in Idaho when a self-sustaining chain reaction was attained in the Argonne Fast Source Reactor (AFSR). Initial criticality was reached on October 29, 1959, with a mass of 21·28 kg of uranium-235 as fuel. The new facility will serve as an important laboratory tool in augmenting studies of fast reactor physics now being carried out in the Argonne Zero Power Critical Facility (ZPR–III) at the Idaho site. The fast reactor is one of the reactor concepts which the Argonne National Laboratory has pioneered at the National Reactor Testing Station.

The AFSR is a small accessible reactor which will extend the laboratory's research capabilities by making available a "guinea pig" source of neutrons for use in developing experimental techniques. The present fast reactors at the site cannot spare the time from their research programmes for this type of study. Supplying as many as 57×10^{10} neutrons per second per square centimetre, the AFSR will be used also to measure the energy range covered by the neutron population existing in a fast reactor. Such measurements are not now possible, although they are extremely important in predicting the behaviour of fast reactor systems. Another use will be to develop a method of measuring the chain-reacting potential of a reactor system from measurements of the statistical fluctuations in the neutron population.

The new reactor will also be utilised for developing and checking new neutron detectors required in fast power reactor experiments; for preparing radioactive metallic foils used to develop counting and radio-chemical techniques; and for checking complex experimental systems in advance of their use in the ZPR–III or other reactors.

The cylindrical reactor core of uranium-235 consists of thin discs 4½in in diameter; these are "canned" in nickel to prevent oxidation. The upper section of the cylinder is fixed, the lower part is movable. To make the reactor critical, the movable lower section is brought towards the stationary upper discs of fissionable material. Surrounding the fissionable core is a blanket of uranium depleted in the isotope U-235. There are five rings of this material, 20in across and totalling 20in in height, together with a top and bottom plug. The unit consisting of the movable lower portion of the core and the lower blanket plug is the safety plug and is actuated by a pneumatic cylinder with a 43in stroke. A space is provided between the core and blanket to allow for the passage of coolant air.

Experiments will be conducted in three horizontal holes which penetrate the blanket; one goes directly through the core, one "grazes" the core centre, and a third beam hole is aimed directly from the reactor face into the centre, terminating ½in from the inner blanket edge. Experiments may also be performed in a 4ft square thermal column which extends from the edge of the blanket to the outer edge of the concrete shielding around the reactor. Filled with graphite blocks, the column provides an experimental region in which neutrons will be slowed down to thermal velocities. Five vertical holes in the blanket contain the control components for the reactor. These controls consist of two safety rods containing blanket material which can be rapidly removed from this region, allowing neutrons to escape and thus decreasing the rate of fission; two shim rods which are adjusted manually to limit reactivity available; and one control rod which is used for fine adjustment. One other horizontal hole is provided to hold a radioactive source of neutrons employed during the start-up of the reactor.

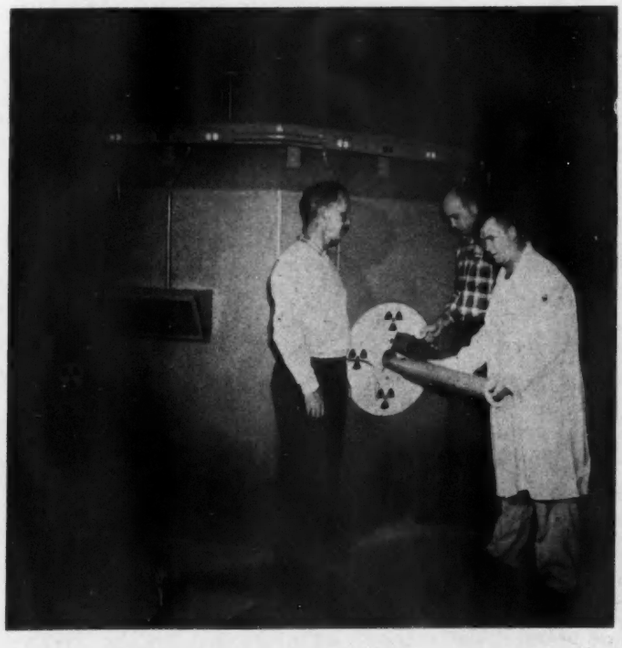


Fig. 1—Concrete shield plug being removed from Argonne Fast Source Reactor in Idaho

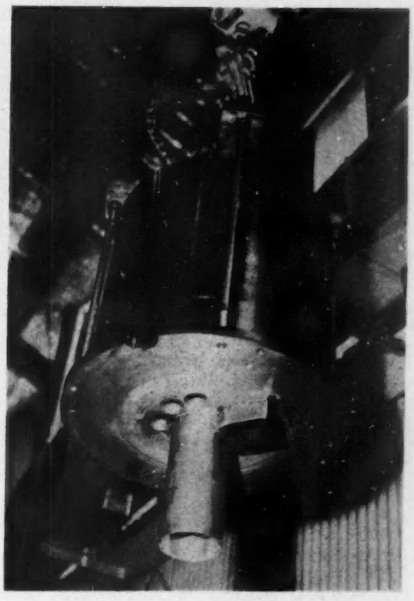


Fig. 2—Depleted uranium blanket assembly being lowered into the Argonne Fast Source Reactor

The AFSR is situated in a 34ft square building behind the laboratory's ZPR-III facility. High density concrete approximately 4ft 6in thick surrounds the reactor to provide shielding against radioactivity. Its overall shape is that of an irregular octagon, 14ft across, 8ft 6in above floor level, and with control mechanisms situated in a pit extending 10ft below floor level. The reactor pit is unoccupied during reactor operation and is only partially shielded. Access to the pit, where core load changes are made, is obtained through a shielded manhole in the floor adjacent to the reactor. The reactor is cooled by air which is filtered after passing through the radioactive system, and then is vented to a stack above the roof. The sub-reactor pit has a separate filtered ventilation system.

Transfer Machining of Die-Cast Cylinder Head

A NEW "Economatic" transfer machine has been designed and built by the Buhr Machine Tool Company, of Ann Arbor, Michigan, for machining the die-cast aluminium cylinder heads of the new Chevrolet "Corvair" compact car. The machine itself is somewhat more compact than a machine for a cast iron cylinder head. However, the reduction in machine size is nowhere near in proportion to the smaller size and lower weight of the new engine. The machine units, including the power units, are identical with standard Buhr units for large transfer machines. It is true that these units have more power capacity than is needed for machining aluminium but they also make possible higher machining feeds and speeds with ample reserve. Furthermore, they have the advantage of standardised component design, have eliminated the cost of much special designing and could be built more quickly. An interesting aspect of this seventeen-station machine is that two methods of transfer from station to station are used—

THE AMERICAN SCENE *(Continued)*

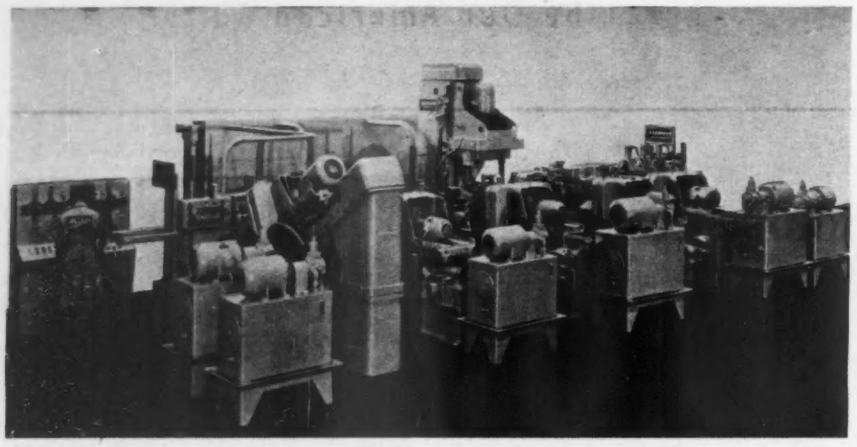


Fig. 1—" Economatic " seventeen-station transfer machine for machining die-cast aluminium cylinder heads

one for the first part of the machine and another one for the second part after the workpiece has been rotated 90 deg. Another aspect is that drill stations are provided as a safety measure even for holes which are cored during the die-casting process.

The ease and speed in working aluminium as compared with cast iron was taken into consideration during preliminary design work. The operations consist of complete drilling, chamfering, boring, reaming and tapping. The machine has seventeen working and idle stations and is separated into two sections by a 90 deg. turn-around. The cylinder heads are skidded along rails through stations 1 to 13 by a rotating transfer bar and are moved through the last three stations by a walking beam. The index step is longer in the first section of the machine because the head is moved lengthwise there. After the operator manually loads a cylinder head at station 1 and presses the " start " push-buttons, the machine automatically processes the part on a nineteen-second cycle. The control of the two sections of the machine is integrated so that the parts pass from one to the other without interruption.

All the cutting tools used on this machine are specifically designed for cutting aluminium and are operated at higher speeds and feeds than would be the case with cast iron. Other major differences between these tools and those for cast iron are that the drills used have fast spirals and polished flutes. All other cutters also have polished flutes.

With die castings, many holes are cored. This does not, however, substantially reduce the number of operations as might at first be expected. Drills are run through these holes to make sure that they are clean. Such " drilling of air " is justified because 100 per cent inspection of the parts for correct hole size and shape would otherwise be required before finishing or tapping. Deep, small holes are cored about half-way through the part and are drilled the remaining distance. Although the number of operations is not much reduced, the amount of work required to finish these parts is considerably less.

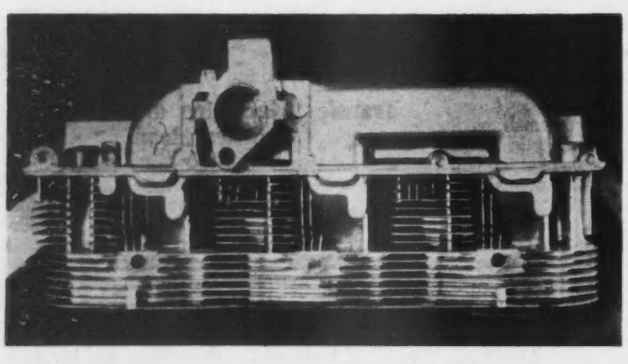


Fig. 2—Die-cast aluminium alloy cylinder head of the Chevrolet " Corvair " compact car

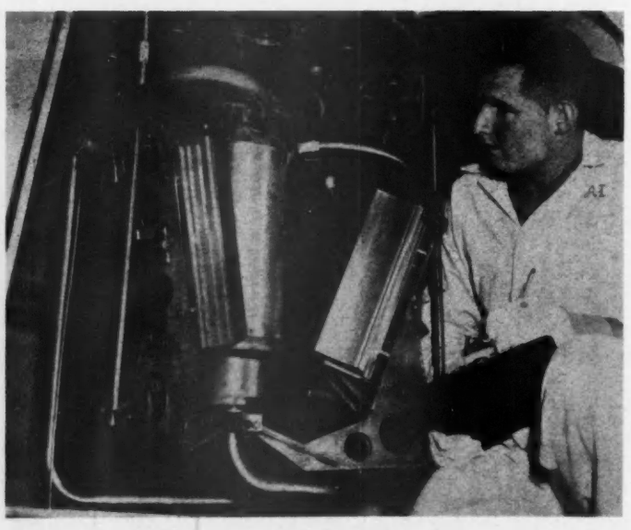
" SNAP " Experimental Nuclear Reactor

THE prototype of a light-weight, high-temperature nuclear reactor to generate heat for the production of 3kW of electric power for space vehicles has been test-operated recently at design power and temperature. The reactor is known as the SNAP Experimental Reactor, weighs approximately 220 lb without shielding and is fuelled with enriched uranium. The reactor was designed and constructed for the Atomic Energy Commission by Atomics International, a division of North American Aviation, of Canoga Park, California, as part of a programme to develop systems for nuclear auxiliary power. The reactor is situated in the Santa Susana Mountains, 25 miles from Los Angeles.

In the ultimate operational device, heat from the reactor will be transferred by a liquid sodium coolant to a boiler containing mercury. The mercury vapour will be fed into a miniature turbo-generator. Such a conversion system has been developed and successfully operated at design conditions with an electrical heat source. The components of the power conversion system were developed by Thompson Ramo Wooldridge, of Cleveland, Ohio.

The SNAP Experimental Reactor takes its name from the Commission programme under which it was developed—" Systems for Nuclear Auxiliary Power." The objective of this programme is the development of compact sources of auxiliary electric power for space vehicle systems. Two basic concepts are being followed. One concept, being developed for the Commission by the Martin Company of Baltimore, Maryland, will use the heat from a radioactive isotope to operate electrical power conversion equipment. Two devices, designated SNAP I and SNAP III, follow this concept. A " proof-of-principle " model of SNAP III has been developed by Martin. The other concept, designated SNAP II, will use the heat from a reactor to operate electrical power conversion equipment. The present experimental reactor follows this concept. The objective of the SNAP reactor programme is to provide devices which will generate many kilowatts of electrical energy for a minimum period of one year in space and which will weigh no more than a few hundred pounds. The device must be capable of withstanding the shocks and vibrations of missile launch, must be capable of unattended, reliable, and automatic operation in a space environment, and must not present a radiation hazard. Such a device would make possible long-lived weather satellites, world-wide television communications, deep-space information transmission and, eventually, inter-planetary travel.

The core of the SNAP II reactor is a hexagonal array of sixty-one cylindrical elements that delivers 50kW (thermal) to a liquid sodium coolant. The fuel elements are Zr H-U^{235} and are 10in long and 1in in diameter. The sodium enters the core at 1000 deg. Fah. and leaves at 1200 deg. Fah., carrying the heat to the mercury boiler, which drives the miniature mercury-vapour turbo-generator. The net electrical output is 3kW, which gives an overall energy-conversion efficiency of 6 per cent.



SNAP II reactor test core which was successfully operated at full power in November, 1959

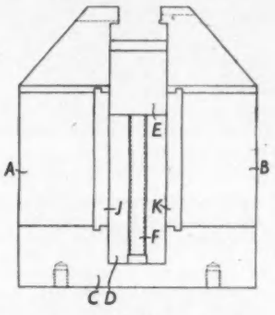
BRITISH PATENT SPECIFICATIONS

The dates printed are those of application and publication on completion. Copies of specifications may be obtained at the Patent Office Sales Branch, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

ELECTRONICS

826,822. March 27, 1958.—MAGNET SYSTEMS FOR MAGNETRONS, Philips Electrical Industries, Ltd., Spencer House, South Place, Finsbury, London, E.2.

In magnetrons having pole pieces attached to them, the forces exerted on the magnetron when it is being arranged on the magnet are so large that the magnetron is liable to be damaged. The process of removing the magnetron from the magnet also requires a fair amount of skill. On the other hand, in magnetrons having built-in pole pieces, which are generally used to produce ultra-short waves, the magnetic field must have a high value, so that it is desirable for the magnetic flux which is available in the magnet system to be utilised as efficiently as possible. According to the invention, a substantially U-shaped magnet system for a magnetron (see drawing) has rectangular blocks of magnetic steel,



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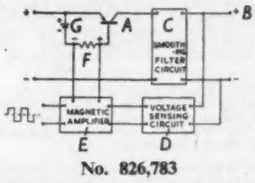
A, *B*, of high coercivity, such as that manufactured under the registered trade mark "Ticonal." The blocks are secured to a soft iron yoke *C* having a middle portion *D* of smaller cross-section, a soft iron block *E* exactly fitting in the resulting recess. This block can be displaced at right angles to the yoke by means of a screwed spindle *F*. The pole-pieces are provided at their upper end with cylindrical recesses for receiving the built-in pole-pieces of the magnetron which are designed as soft iron cylinders. The facing surfaces of the blocks of magnet steel are lined with brass sheets *J* and *K* respectively. As soon as the block *E* is moved towards the pole-pieces the magnetic field in the magnetron is weakened because the cross-sectional area of the fixed yoke *C* is materially reduced. This effect increases as the block, acting as a magnetic shunt, is moved further between the pole-pieces, so that the magnetron can be mounted on or removed from the magnet system without difficulty.—*January* 20, 1960.

ELECTRICAL ENGINEERING

826,783. March 19, 1957.—ELECTRICAL SUPPLY REGULATORS, National Research Development Corporation, 1, Tilney Street, London, W.1. (*Inventor: Arthur George Milnes.*)

When transistors are used in electrical supply regulators, the power handling capacity of the regulator is limited by the amount of power which can safely be dissipated in the transistor. It is an object of the present invention to provide a transistor electrical supply regulator capable of delivering a



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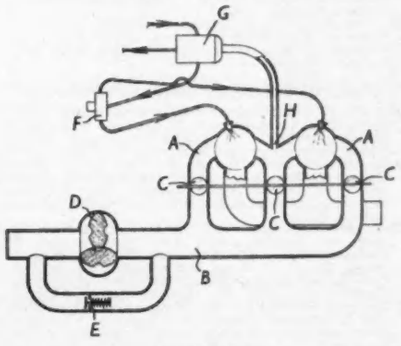
larger amount of power than hitherto. The basic circuit arrangement shown in the drawing comprises a p-n-p power transistor *A* whose collector is connected to a load terminal *B* via a smoothing filter circuit *C* and whose emitter is connected to the positive terminal of an unregulated voltage source. A voltage-sensing circuit *D* provides a current output which is applied to a control winding of a magnetic amplifier *E*. The magnetic amplifier has a square-wave a.c. input and gives a pulse-width modulated output which is applied across a resistor *F*. The emitter of the transistor is connected to its base via a voltage source *G* and the resistor *F* in series. Thus, the voltage between the emitter and the base of the power transistor is the sum of the voltages across *G* and *F* and, therefore, may be made to reverse in polarity in step with the output of the magnetic amplifier. Thus, the transistor is controlled so that the current flow through it is switched alternately on and off, the on/off ratio being varied in accordance with the output voltage, or output current, of the regulator so as to maintain the output voltage or current at a desired value. The specification also shows a detailed circuit of a regulator operating on the above principle and a schematic circuit of a regulator designed to convert a voltage level at the input to a different voltage level at the output.—*January* 20, 1960.

INTERNAL COMBUSTION ENGINES

826,994. November 7, 1956.—TWO-STROKE ENGINES, Societe Anonyme Andre Citroen, 117/167, Quai de Javel, Paris, France.

An object of this invention is to improve two-stroke internal combustion engines of the fuel injection type so that a correct fuel delivery rate will be maintained regardless of the scavenging air ratio, and hence of the power output of the engine. An engine in accordance with the invention is described by way of example with reference to the accompanying drawing. As shown in the drawing, the engine includes the intake ports of the two cylinders which are connected by intake conduits *A* connected with a



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common manifold *B*. Fitted in each of the conduits *A* is a butterfly valve *C* for regulation of the scavenging air ratio. The intake manifold is connected with a compressor *D* which supplies the scavenging air and is by-passed by check valve *E* serving to prevent the compressor discharge pressure from rising excessively when the valves *C* are closed. The injection nozzles are supplied through a distributor valve *F*, the operation of which is synchronised with that of the engine, and a metering valve *G* controlling the flow of fuel. The metering valve is controlled in response to the scavenging air pressure which is picked off at the point *H* between a valve *C* and the cylinders, an increase in said pressure increasing the rate of fuel delivery and vice versa.—*January* 27, 1960.

ELECTRICAL ENGINEERING

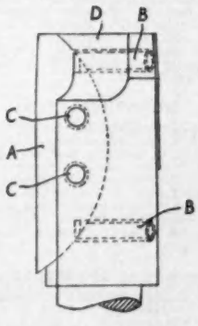
826,987. October 11, 1956.—SPEED CONTROL FOR A.C. MOTOR, Clarke, Chapman and Co., Ltd., Victoria Works, Gateshead, 8, Co. Durham, and Francis Charles Howlett, 76, Kenton Lane, Newcastle on Tyne.

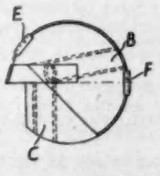
This invention relates to speed control mechanism for a.c. motors and in particular to three-phase slipring induction motors. It may be used with advantage in cranes, winches and the like. Various methods have been proposed whereby a motor having resistance in the rotor circuit suitable for a heavy load is artificially loaded by means of a brake, the brake drag thus being added to the light load and forcing the speed down. This will give a slow speed control for light loads with the same characteristics as if the motor was operating on a heavy load. According to the present invention, a d.c. motor is coupled to the shaft of the a.c. hoist motor. When the controller is moved to the first hoist step, the a.c. motor is started with resistance in its rotor circuit, and current is also supplied from a rectifier to the d.c. motor, this circuit including the coil of an electromagnetic brake. At this moment the d.c. motor current is high and fully energises the brake, which is released and allows the hoist motor to revolve. As the hoist motor speeds up and the back e.m.f. of the d.c. motor increases, the current through the brake coil will fall until a point is reached at which the brake is partly applied to the hoist motor and prevents any further rise in speed. If the hoist motor slows down, the back e.m.f. of the d.c. motor decreases and the current in the brake coil increases, so that the drag on the hoist motor is reduced. Stability will thus be reached at a speed where the hoisting motor torque (which decreases with speed) balances the load plus the brake drag (which increases with speed). The speed at which this balance occurs is a matter of design, but it is convenient to make this speed (referred to as the "creep" speed) between 10 per cent and 20 per cent of the normal speed. When lowering a load, with the device described connected to one or more of the lowering steps of the hoist motor, the brake will be operated at the creep speed and lowering of the load will take place at a low speed. Stability will be reached at a motor speed where the brake drag balances the load plus the motor torque. The hoisting motor will be forced into motoring at a low speed by the drag of the brake.—*January* 27, 1960.

MACHINE TOOLS

826,956. February 29, 1956.—MACHINE REAMERS, Maschinen- und Prazisionswerkzeugfabrik G.m.b.H., Aalen/Wrutt, Germany.

In the machine reamers described there is provided a three-point guidance which is so arranged that the three guide points comprise the exchangeable cutter blade of the reamer and two non-cutting guide elements distributed around the periphery of the carrier body. One construction is shown by way of example in the accompanying drawings wherein the carrier body of the reamer has a slot in which the reamer blade *A* is inserted in the usual way. The adjustment of this blade to the required radius is





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effected by screws in holes *B*, whilst it is held by screws in holes *C*. The leading end of the blade and carrier body are tapered at about 3 deg. and a chip chamber *D* is provided at the leading end of the tool. A hard metal strip *E* inserted in the body adjacent the back of the blade serves as a guide and operates as a control face following the blade. In general it has proved advantageous if the angle between the cutting edge of the blade and the centre of the guide is about 40 deg. A second hard metal guide *F* is arranged diametrically opposite the cutting edge. By this arrangement, seizing or eccentric operation is avoided. The blade is relieved in such a way that a positive rake angle is produced and the two guide elements give a definite support in relation to the cutting edge in such a manner that the cutting pressure of the tool is absorbed in the optimum manner.—*January* 27, 1960.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

To-day, Feb. 26.—COVENTRY AND DISTRICT BRANCH : E.M.E.B. Sports and Social Club, Merrick Lodge, Sandy Lane, Coventry. Films, "Kermesse Fantastique" and "Essential Rays," 7.45 p.m.

Tues., March 1.—ESSEX BRANCH : Angel Hotel, Ilford, Essex, "Insulating Varnishes," J. S. Hann, 8 p.m. ★ NEWCASTLE UPON TYNE AND DISTRICT BRANCH : Crown Hotel, Clayton Street, Newcastle upon Tyne, "The Kariba Project," 7.30 p.m. ★ READING AND DISTRICTS BRANCH : "Marquis of Lorne," Friar Street, Reading. Lecturettes by Branch Members, 7.30 p.m. ★ WEST LONDON BRANCH : Windsor Castle Hotel, 134, King Street, Hammersmith, London, W.6, "Silicone Rectifiers," D. R. Coleman, 7.30 p.m.

Wed., March 2.—HALIFAX BRANCH : Crown Hotel, Horton Street, Halifax, "Transatlantic Telephone Cables, 1956–59," 7.45 p.m. ★ NORTH LONDON BRANCH : Wood Green Civic Centre, Town Hall, London, N.22. Film Show, 8 p.m. ★ PRESTON BRANCH : R.A.F.A. Club, East View, Preston, "Electricity and Productivity," J. M. Ashcroft, 7.30 p.m.

Fri., March 4.—LIVERPOOL AND DISTRICT BRANCH : Industrial Development Centre, M.A.N.W.E.B., Paradise Street, Liverpool, 1, "Town Distribution Network," 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Thurs., March 3.—COMPUTER GROUP : London School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Time Sharing in On-Line Computer Applications," A. St. Johnston, 6.30 p.m. ★ NORTH WESTERN SECTION : Reynolds Hall, College of Technology, Sackville Street, Manchester, "Electronics in Oceanography," M. J. Tucker, 6.30 p.m.

Fri., March 4.—SOUTH MIDLANDS SECTION : North Gloucestershire Technical College, Cheltenham, "The Use of Radio Aids in the Control of Modern Transport Aircraft," K. Fearnside, 7 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., March 5.—Lancaster Room, Caxton Hall, London, S.W.1, Symposium on "The Exploration of the Moon"; "Description of the Moon," P. Moore; "Unmanned Exploration of the Moon," K. W. Gatland, and "Manned Exploration of the Moon," W. N. Neat, 2.30 p.m.

CEMENT AND CONCRETE ASSOCIATION

To-day, Feb. 26.—Medway College of Technology, Maidstone Road, Chatham, "Practical Formwork, Design and Construction for Concrete," J. G. Richardson, 7.15 p.m.

ILLUMINATING ENGINEERING SOCIETY

Wed., March 2.—EDINBURGH CENTRE : Y.M.C.A. Social Room, 14, South St. Andrew Street, Edinburgh, "Design and Aiming of Area Floodlighting Installations," G. K. Lambert, 6.15 p.m. ★ NEWCASTLE UPON TYNE CENTRE : Room B.7, Percy Buildings, King's College, Queen Victoria Road, Newcastle upon Tyne, 1, "Designed Appearance Lighting of Gloucester Cathedral," J. M. Waldram, 6.15 p.m.

Thurs., March 3.—GLASGOW CENTRE : British Lighting Council, 29, St. Vincent Place, Glasgow, C.1, "Design and Aiming of Area Floodlighting Installations," G. K. Lambert; Annual General Meeting, 6.30 p.m.

INSTITUTE OF FUEL

Tues., March 1.—NORTH-EASTERN SECTION : Chemistry Lecture Theatre No. 3, King's College, Newcastle upon Tyne, "The Use of Ammonia to Eliminate Acid Dewing in Stoker Fired Boilers," T. J. P. Pearce, and D. R. Goodman, 5.30 p.m.

Thurs., March 3.—MERSEYSIDE SUB-SECTION : Liverpool Engineering Society's Rooms, 9, The Temple, Dale Street, Liverpool, Annual General Meeting and Films, 7 p.m.

Fri., March 4.—SOUTH WALES SECTION : South Wales Electricity Board Showrooms, Kingsway, Swansea, "Steam Utilization," D. P. Golch, 6 p.m.

INSTITUTE OF PETROLEUM

Wed., March 2.—LONDON BRANCH : 61, New Cavendish Street, London, W.1, "Corrosion Problems in the Lacq Field," M. Estavoyer, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., March 3.—Institute of Marine Engineers, The Memorial Building, 76, Mark Lane, London, E.C.3, "European Refrigerated Transport by Railway," E. Baumgartner, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Thurs., March 3.—WESTERN CENTRE : Royal Hotel, Bristol, "Problems in Developing the High-Speed Diesel Engine," B. W. Millington, 6.30 p.m.

INSTITUTE OF WELDING

Thurs., March 3.—LONDON BRANCH : 54, Princes Gate, London, S.W.7, Third Annual Lecture, "The Influence of Welding on the Design of Ships," W. G. John, 6 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., March 1.—Great George Street, Westminster, London, S.W.1, "Underground Station for Western District Post Office, London,"; "Design and Control," S. Blackford, and E. W. Cuthbert, and "Construction," V. H. Collingridge and R. E. Tuckwell, 5.30 p.m.

Thurs., March 3.—GRAHAM CLARK LECTURE : Institution of Electrical Engineers, Savoy Place, London, W.C.2, Joint Meeting with the Institution of Mechanical Engineers and the Institution of Electrical Engineers, "The Engineer and Civilisation," Sir Hugh Beaver, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Monday, Feb. 29.—NORTH-EASTERN MEASUREMENT AND ELECTRONICS GROUP : Rutherford College of Technology, Newcastle upon Tyne, "Radio Aspects of the International Geophysical Year," R. L. Smith-Rose, 6.15 p.m.

Tues., March 1.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, "Digital Computer Developments at Manchester University," T. Kilburn; "A Digital Computer Store with Very Short Read Time," T. Kilburn and R. L. Grimsdale; "High-Speed Light Output Signals from Electroluminescent Storage Systems," G. R. Hoffman, D. H. Smith and D. C. Jeffreys, and "Ferrite Magnetic Core Memory Systems with Rapid Cycle Times," D. B. G. Edwards, M. J. Lanigan and T. Kilburn, 5.30 p.m. ★ EAST MIDLAND CENTRE : Electricity Service Depot, Station Street, Burton-on-Trent, "Generator/Motor Problems in Pumped-Storage Installations," J. H. Walker, 6.30 p.m. ★ NORTH MIDLAND CENTRE : Leeds and County Conservative Club, South Parade, Leeds, 1, "The Transmission of News Film over the Transatlantic Cable," C. B. B. Wood and I. J. Shelley, 6.30 p.m. ★ NORTH-WESTERN CENTRE : Engineers' Club, Manchester, "Water-Turbine-Driven Induction Generators," C. L. C. Allan, 6.15 p.m.

Wed., March 2.—TEES-SIDE SUB-CENTRE : Cleveland Scientific and Technical Institution, Middlesbrough, "The 'Deltic' Locomotive," C. M. Cock, 6.30 p.m. ★ SOUTH-WEST SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, C.2, "Research on the Performance of High-Voltage Insulators in Polluted Atmospheres," J. S. Forrest, P. J. Lambeth and D. F. Oakeshott, 6 p.m. ★ SOUTHERN CENTRE : The University, Southampton, "Electro-thermal Problems," K. L. Morphew, 7 p.m.

Thurs., March 3.—SIXTH GRAHAM CLARK LECTURE : Savoy Place, London, W.C.2, Joint Meeting with the Institution of Mechanical Engineers and the Institution of Civil Engineers, "The Engineer and Civilisation," Sir Hugh Beaver, 5.30 p.m. ★ SOUTHERN CENTRE : South Dorset Technical College, Weymouth, "Nuclear Magnetism," J. E. Wood, 6.30 p.m. LONDON GRADUATE AND STUDENT SECTION : Visit to Vauxhall Motors, Ltd., Luton, 8.45 a.m.

Fri., March 4.—MEDICAL ELECTRONICS DISCUSSION GROUP : Savoy Place, London, W.C.2, Discussion on "Direct Writing Oscillographs," opened by A. Smale, and S. N. Pocock, 6 p.m. ★ NORTH-EASTERN CENTRE : Technical College, Carlisle, "The Design and Performance of the Gas-Filled Cable System," E. P. G. Thornton and D. H. Booth, 7 p.m.

Sat., March 5.—LONDON GRADUATE AND STUDENT SECTION : Visit to Big Ben Clock Tower (Clock Mechanism and Broadcast Arrangements), 10.30 a.m.

INSTITUTION OF ENGINEERING DESIGNERS

Wed., March 2.—MIDLANDS BRANCH : Queens Hotel, Birmingham, "Plastics in Industry," C. C. Morgan, 7 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

To-day, Feb. 26.—Robert Gordon's Technical College, Aberdeen, "Vibration Problems in Marine Machinery and their Solution," W. McLaughlin, 7.45 p.m.

INSTITUTION OF HIGHWAY ENGINEERS

Wed., March 2.—EAST ANGLIAN BRANCH : Assembly House, Theatre Street, Norwich, "The Economics of Road Improvement," D. V. Reynolds, 6.45 p.m.

Thurs., March 3.—YORKSHIRE AND LINCOLNSHIRE BRANCH : North Eastern Hotel, Goole, "Formation and Compaction of Embankments," 7 p.m.

Fri., March 4.—LONDON BRANCH : Institution of Structural Engineers, 11, Upper Belgrave Street, London, S.W.1, "New Methods of Automatic Traffic Control," E. Bailey and E. Thorpe, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

Sat., Feb. 27.—E. MIDLANDS GRADUATES' SECTION : Visit to British Transport Commission Carriage and Wagon Works, Litchurch, Derby, 10 a.m. ★ LONDON GRADUATES' SECTION : Visit to Hancock and Co. (Engineers), Ltd., Croydon, 10 a.m.

Mon., Feb. 29.—NORTH EASTERN BRANCH : Lecture Theatre, Literary and Philosophical Society, Westgate Road, Newcastle upon Tyne, Annual General Meeting; and "The Design and Operation of Blyth Power Station," A. E. Powell and E. Forth, 6 p.m.

Tues., March 1.—AUTOMOBILE DIVISION : 1, Birdcage Walk, Westminster, London, S.W.1, James Clayton Lecture, "The Chemistry of Future High-Compression Engines," Wheeler G. Lovell, 6 p.m. ★ SOUTH WALES BRANCH : South Wales Institute of Engineers, Cardiff, Symposium on "Automatic Control," 3 p.m. and 6 p.m. ★ NORTH EASTERN GRADUATES' SECTION : Rutherford College, Newcastle upon Tyne, Annual Meeting followed by several short papers on "Methods of Finishing the Surfaces of Engineering Components," 6.30 p.m.

Wed., March 2.—NUCLEAR PANEL : 1, Birdcage Walk, Westminster, London, S.W.1, Discussion on "The Role of Formal Education and Training in Nuclear Power Developments," opened by J. M. Kay and J. Diamond, 6 p.m. ★ EAST MIDLANDS BRANCH : College of Technology, Chesterfield, "Properties of Materials used for Surface Protection of Steel," P. Benham, 7.15 p.m. ★ YORKSHIRE BRANCH : The University, St. George's Square, Sheffield, "High-Speed Precision Forging with Hydraulic Presses," F. H. Towler and B. C. Wilkins, 6.30 p.m.

Thurs., March 3.—GRAHAM CLARK LECTURE : Savoy Place, London, W.C.2, Joint meeting with the Institution of Electrical Engineers and the Institution of Civil Engineers, "The Engineer and Civilisation," Sir Hugh Beaver, 6 p.m. ★ SCOTTISH BRANCH : Royal College of Science and Technology, Glasgow, "Noise and Hearing : Physiological Aspects," W. Burns, and "Origins of Diesel-engine Noise," A. E. Austen, and T. Priede, 7.30 p.m. ★ SOUTHERN BRANCH : Technical College, Boundary Road, Farnborough, Hants, "The Potentialities of Accurate Measurement and Control in Production Engineering," J. Loxham, 7.30 p.m. ★ EAST MIDLANDS GRADUATES' SECTION : Gas Showrooms, Church Street, Peterborough, "Some Aspects of Machine Tool Design for the Future," F. A. Lewis, 7.15 p.m. ★ SOUTHERN GRADUATES' SECTION : Technical College, Brighton, Chairman's Address, "High-energy Particle Accelerators" P. Clee, 7 p.m. ★ SOUTHERN GRADUATES' SECTION : Technical College, Maidstone, "Patents," R. E. Tree, 7.30 p.m. ★ YORKSHIRE GRADUATES' SECTION : Grand Hotel, Sheffield, "Some Aspects of Rolling Plant Design," D. R. Howard, 6.30 p.m.

Fri., March 4.—SCOTTISH BRANCH : Robert Gordon's College, Aberdeen, "Noise and Hearing : Physiological Aspects," W. Burns and "Origins of Diesel-engine Noise," A. E. Austen and T. Priede, 7.30 p.m.

INSTITUTION OF PLANT ENGINEERS

Mon., Feb. 29.—WEST AND EAST YORKSHIRE BRANCH : Houldsworth School of Applied Science, The University, Leeds, "Railway Electrification," W. T. Stephenson, 7.30 p.m.

Tues., March 1.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, Strand, W.C.2, Annual General Meeting, 6.30 p.m., and "The 'Deltic' Locomotive," C. M. Cock, 7.15 p.m. ★ PETERBOROUGH BRANCH : White Lion Hotel, Church Street, Peterborough, "Split Roller Bearings," C. Orchard, and P. W. R. Blake, 7.30 p.m.

Wed., March 2.—EDINBURGH BRANCH : 25, Charlotte Square, Edinburgh, Annual General Meeting, 7 p.m. ★ GLASGOW BRANCH : Scottish Building Centre, 425-427, Sauchiehall Street, Glasgow, Annual General Meeting, 7.15 p.m. ★ SOUTHERN BRANCH : Polygon Hotel, Southampton, Annual General Meeting, 7.30 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Fri., March 4.—SOUTHERN REGION : Polygon Hotel, Southampton, Annual General Meeting, 8 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Feb. 26.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Manufacture and Use of Metal Sinterings," B. H. Swan, 7 p.m.

Fri., March 4.—Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Windmills in Colour," Rex Wailes, 7 p.m.

LIVERPOOL METALLURGICAL SOCIETY

Thurs., March 3.—Library, Dept. of Metallurgy, The University, Liverpool, 3, Joint Meeting with the Institute of Metals, "Semi-Conductors," R. P. Chasmar, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

To-day, Feb. 26.—Engineers' Club, Albert Square, Manchester, "The Development of the Plano Milling Machine," J. Atherton, 6.45 p.m.

NEWCOMEN SOCIETY

Wed., March 2.—Science Museum, London, S.W.7, "Simon Goodrich and his Work as an Engineer, Part III, 1813–23," A. S. Crosley, 5.30 p.m.

PLASTICS INSTITUTE

Tues., March 1.—LONDON SECTION : Wellcome Building, 183–193, Euston Road, London, N.W.1, "Recent Investigations into Polymer Degradation," N. Grassie, 6.30 p.m.

REGIONAL ADVISORY COUNCIL FOR TECHNOLOGICAL EDUCATION

Tues., March 8.—Fyvie Hall, The Polytechnic, Regent Street, London, W.1, Conference on "The Changing Pattern of Electrical Engineering Education and Training," 10.30 a.m. to 12.30 p.m.

REINFORCED CONCRETE ASSOCIATION

Tues., March 1.—NORTH-WESTERN BRANCH : College of Technology, Sackville Street, Manchester, "Architectural Mannerisms in Reinforced Concrete," S. G. Besant Roberts, 6.45 p.m.

Wed., March 2.—NORTH-WESTERN BRANCH : Liverpool Engineering Society, The Temple, 24, Dale Street, Liverpool, "Architectural Mannerisms in Reinforced Concrete," S. G. Besant Roberts, 6.30 p.m.

ROYAL ASTRONOMICAL SOCIETY AND ROYAL METEOROLOGICAL SOCIETY

Fri., March 4.—Royal Society of Arts, John Adam Street, London, W.C.2, Joint Discussion on "The British Rocket Programme," opened by H. S. W. Massey, 2.30 p.m.

ROYAL METEOROLOGICAL SOCIETY

Wed., March 2.—49, Cromwell Road, London, S.W.7, "Weather, Soil and Plant Factors in Hydrology," H. L. Penman, 5.30 p.m.

ROYAL SOCIETY OF ARTS

Mon., Feb. 29.—CANTOR LECTURE : John Adam Street, Adelphi, London, W.C.2, "The Fuel and Power Industries and National Prosperity—Natural and Manufactured Gas," A. Parker, 6 p.m.

Advanced Engineering Courses

O.E.E.C. Courses on Nuclear Energy for Engineers and Technical Industrialists. Two international courses arranged by the European Nuclear Energy Agency of the O.E.E.C. One course will be at the Centre d'Etudes Nucléaires at **Saclay**, France, and the other at the Atomic Energy Research Establishment, Harwell. Each course will be open to some fifty participants from O.E.E.C. countries, and will cover the technical, economic and industrial aspects of nuclear energy. The course at Saclay (French language) will take place from June 27 to July 8; the the Harwell course, in English, from July 4 to 15. Further information can be obtained from O.E.E.C. European Nuclear Energy Agency, 38, Boulevard Suchet, Paris, 16e.

Refresher Courses for Older Graduates. DEPARTMENT OF METALLURGY, BATTERSEA COLLEGE OF TECHNOLOGY, London, S.W.11. Three- to four-day courses by members of the College staff and visiting lecturers. "The Structure of Metals and Alloys," Easter vacation, April; "Developments in Foundry Practice," Summer vacation, July: "Austenite Transformation—The Present Position," Summer vacation, September.

Operational Research. INSTITUTE FOR ENGINEERING PRODUCTION, THE UNIVERSITY OF BIRMINGHAM, 16, Norfolk Road, Birmingham, 15. The general purpose of the course is to enable industrial managers, senior production engineers and operational research and work study specialists to meet together with leading authorities in the operational research field and to engage upon discussions and group studies on modern developments in the application of operational research to industrial productivity problems. The course runs from 9.30 a.m., Monday, April 4, until 5.30 p.m., Thursday, April 14. Inclusive charge for the two-week residential course is fifty-five guineas.

Health Physics (Radiation Protection). NUCLEAR TECHNOLOGY LABORATORIES DEPARTMENT OF CHEMICAL ENGINEERING AND CHEMICAL TECHNOLOGY, IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, South Kensington, London, S.W.7. A summer school in health physics (radiation protection) arranged by Hugh D. Evans. The course will be of two weeks' duration, starting on Monday, July 4, and should be of interest to university radiation protection officers, industrial safety officers concerned with radiation and radioactive hazards, medical officers of health, factory inspectors and others concerned with radiation protection. Fee twenty-five guineas (exclusive of residence).

Metal Fatigue. THE UNIVERSITY, BRISTOL. The course runs from March 28 to April 1 and is intended for engineers and for metallurgists and physicists interested in engineering matters. Fee five guineas, charge for accommodation at the Hawthorns Hotel, ten guineas.

The Design of Industrial Experiments. INSTITUTE FOR ENGINEERING PRODUCTION, THE UNIVERSITY OF BIRMINGHAM, 16, Norfolk Road, Birmingham, 15. The course, which will be held from 9.30 a.m., Monday, March 21, until 3.30 p.m., Friday, April 1, covers the theory of experimental design from the basic principles to the analysis and interpretation of the results. Inclusive charge for the two-week residential course is fifty-five guineas.

Statistical Quality Control. INSTITUTE FOR ENGINEERING PRODUCTION, THE UNIVERSITY OF BIRMINGHAM, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham, 15. The course will be held from 9.30 a.m. Monday, April 25, until 3.30 p.m., Friday, May 6. It will give the general theory of control charts and acceptance sampling plans and will include some recent developments in the field of statistical quality control. Inclusive charge for the two-week residential course is fifty-five guineas.

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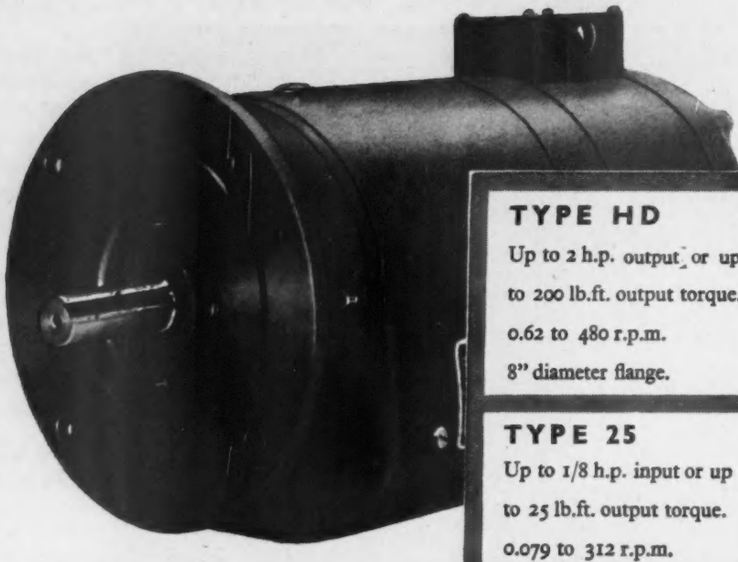

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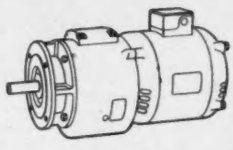

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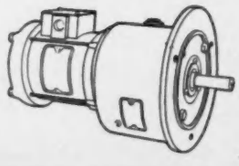

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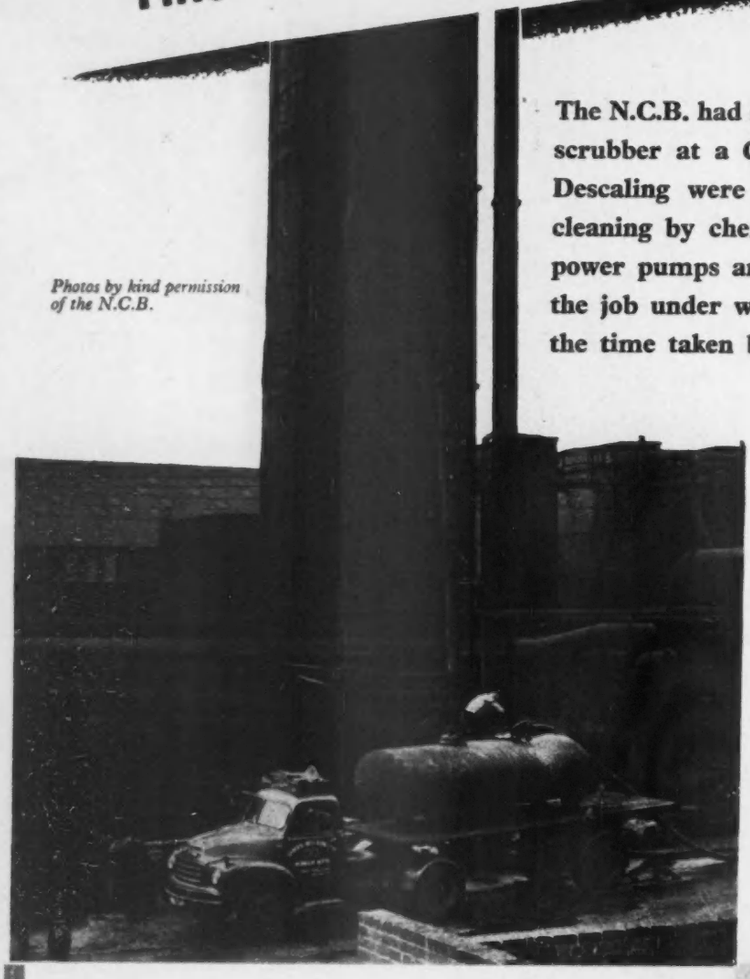

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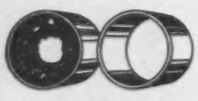

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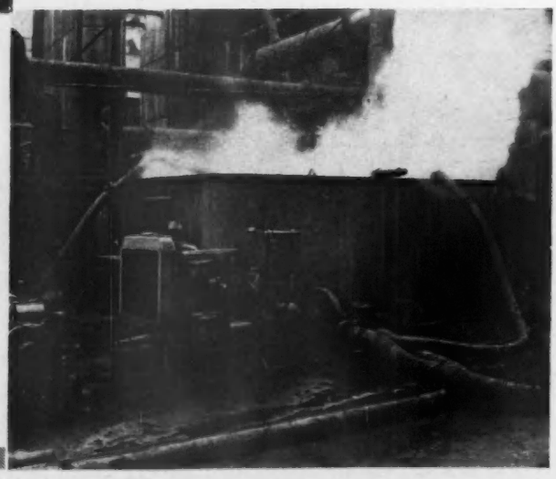

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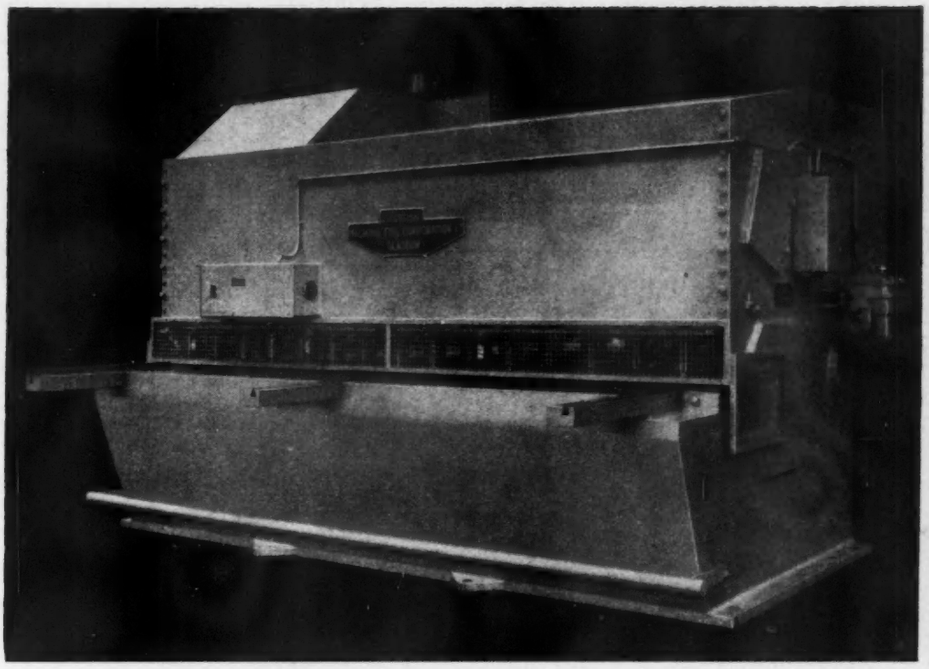

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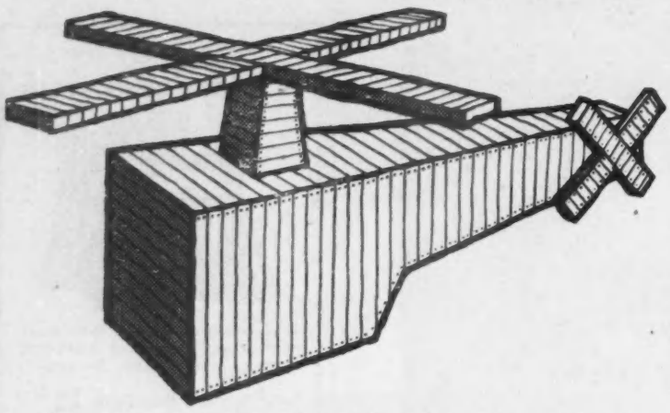

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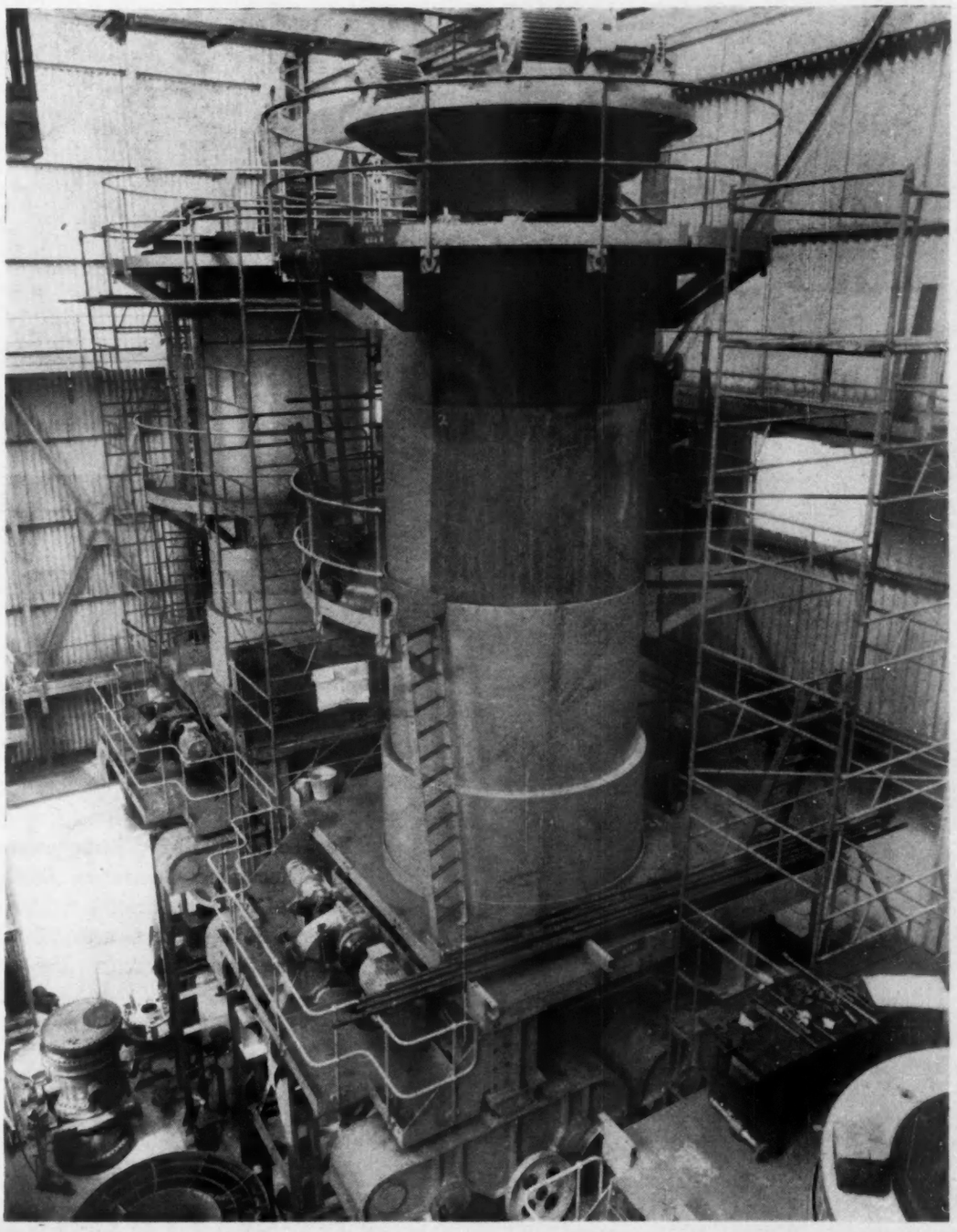

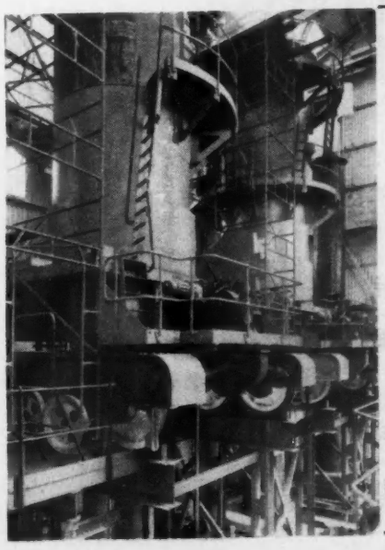

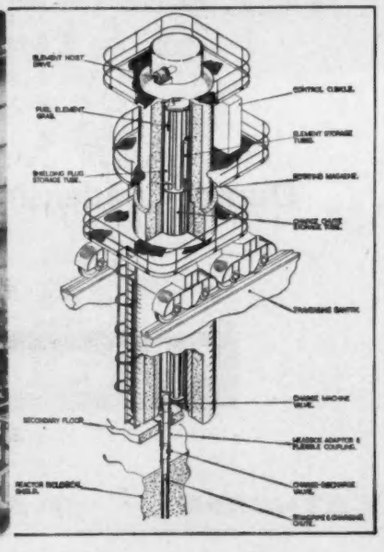

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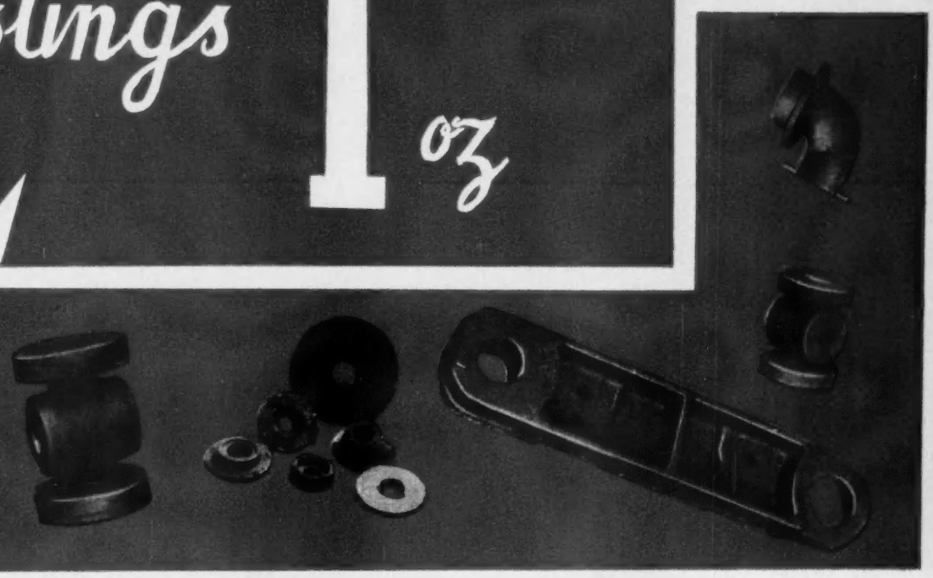

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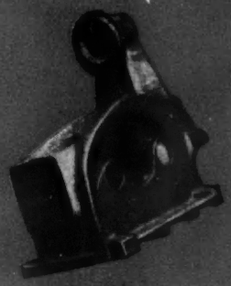

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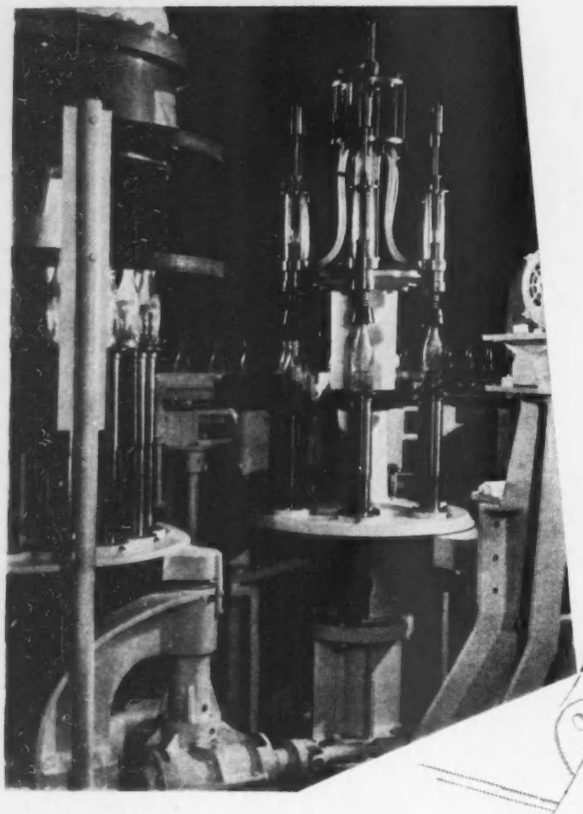

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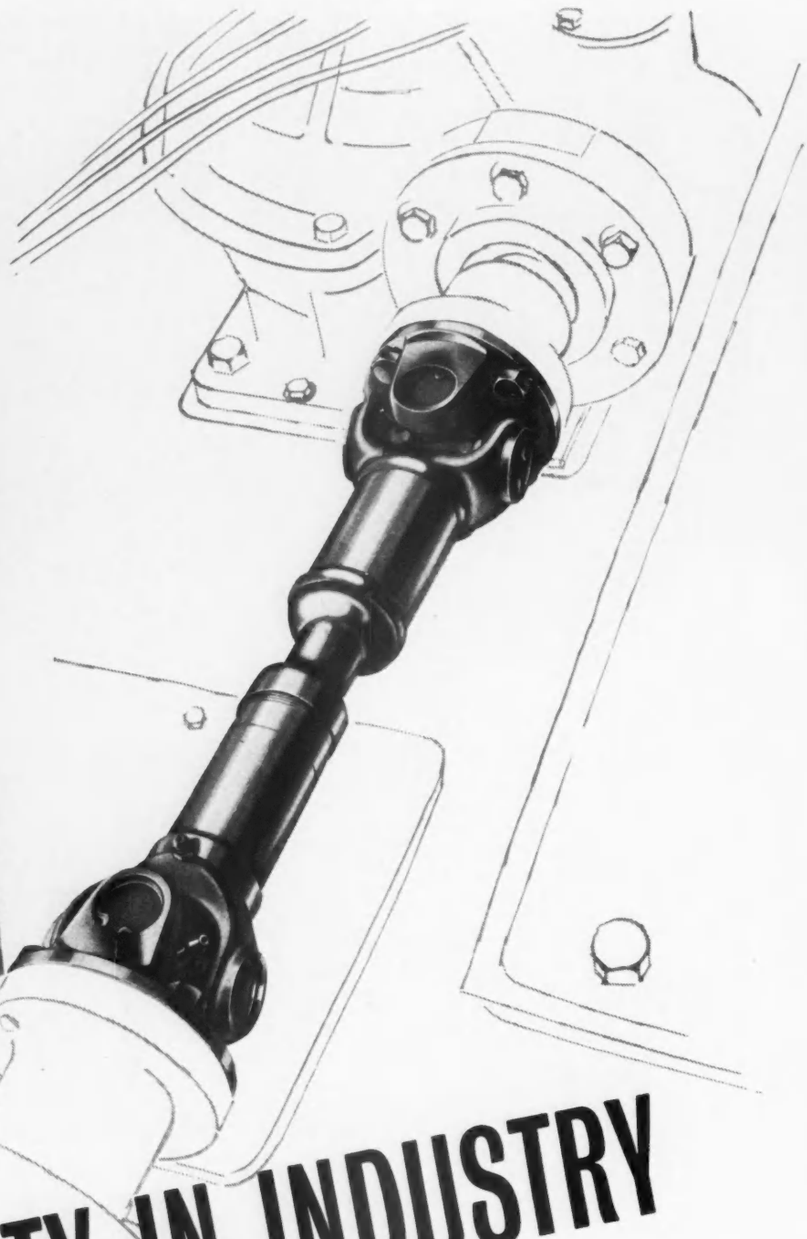

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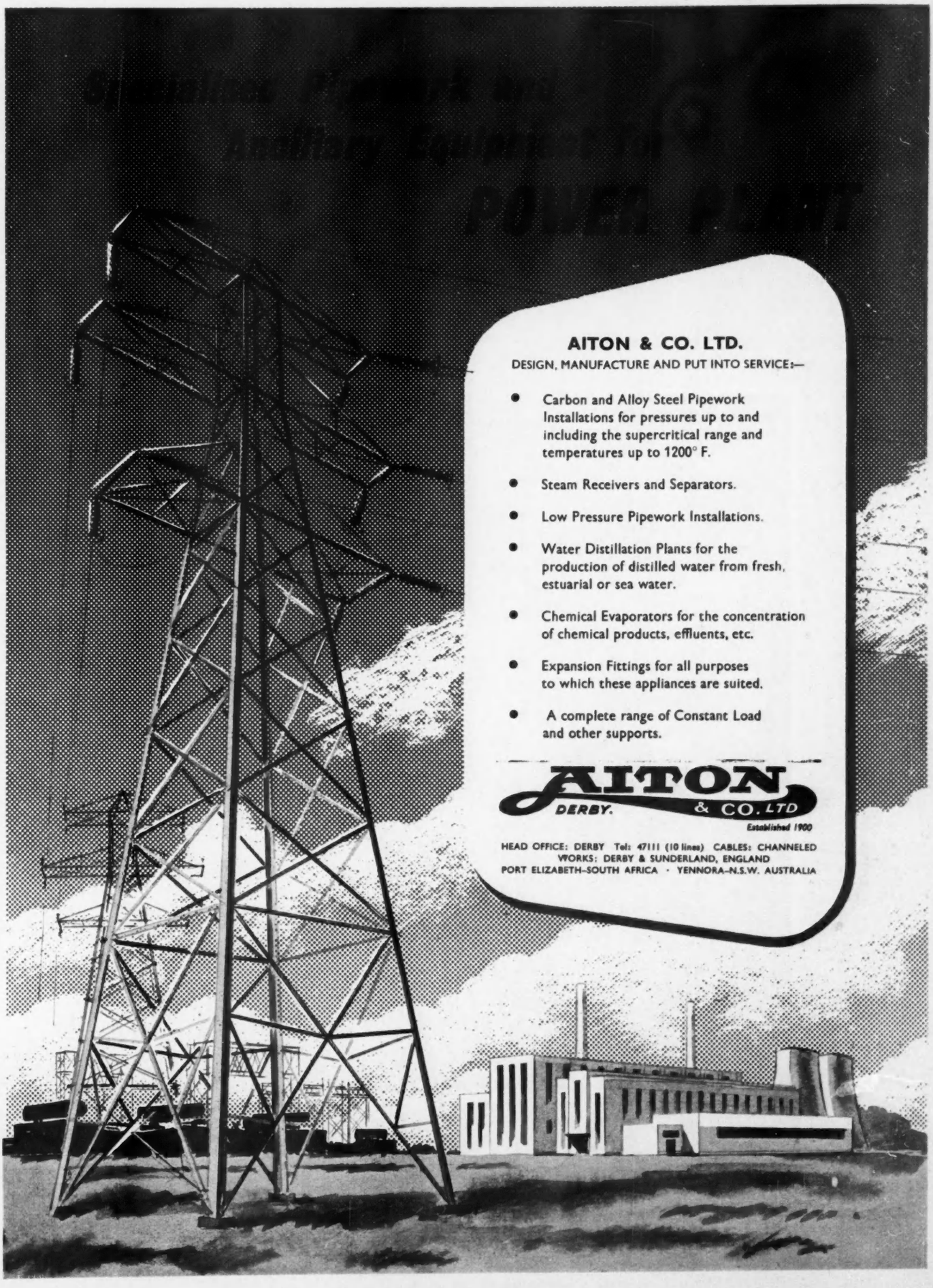
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M

At Round Oak Steelworks—a lifetime of service from father, son and grandson, working with skill and pride in a family tradition of service, coupled with modern scientific facilities, produces high grade steels. The creative material used by man as the foundation on which progress marches.

CREATIVE MATERIAL

LIONHOUSE

Basic Open-Hearth and Electric-Arc Furnace Steels, Carbon, Case-Hardening, Forging, Bright-drawing, Machining, Free-cutting and Alloy steels to all specifications. Sections, Plate, Rounds, Squares, Billets, Blooms and Slabs.

MEN IN ACTION —THE RHYTHM OF CO-ORDINATION 'F' furnace men fettling in the Melting Shop at Round Oak

ROUND OAK STEEL WORKS LIMITED

Brierley Hill, Staffordshire

ALSO AT: LONDON · MANCHESTER · SHEFFIELD

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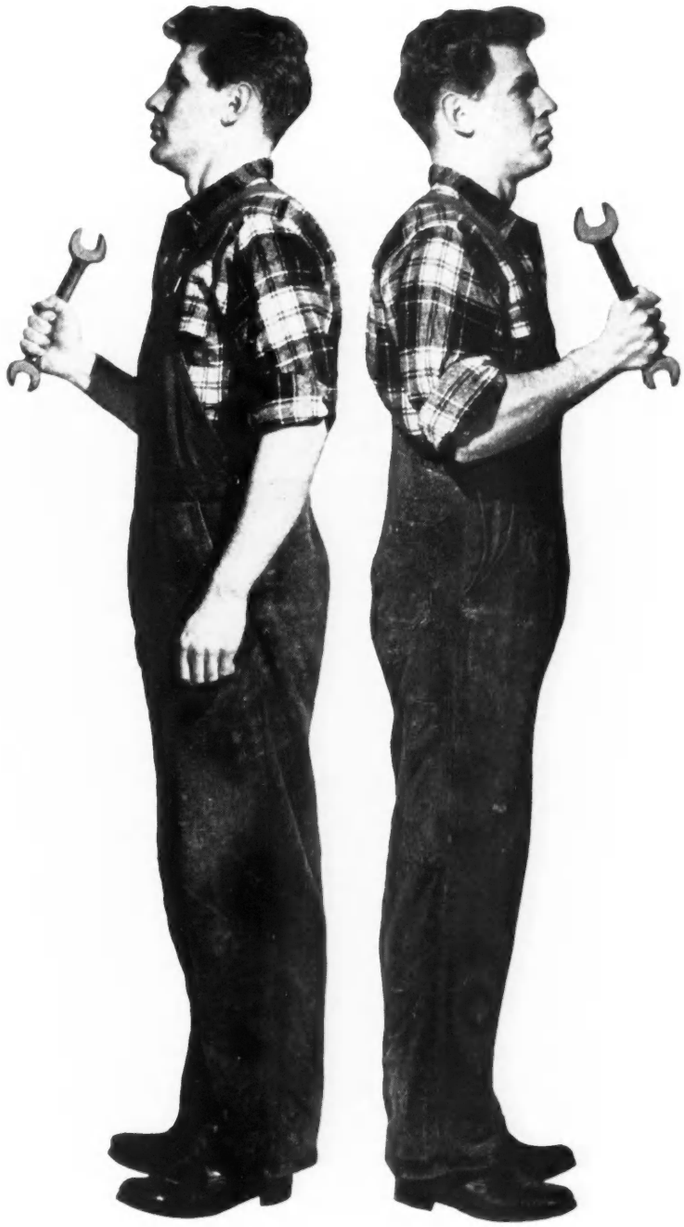
A TI COMPANY

It takes him 60 minutes* to assemble 100 $\frac{1}{4}$" full nuts and jam nuts

It takes him 40 minutes* to assemble 100 $\frac{1}{4}$" Nyloc self-locking nuts!



By using one ¼" Nyloc self-locking nut instead of a full nut and a jam nut you could save 20 minutes and approximately 2 - on every hundred assemblies. On some jobs, Simmonds self-locking nuts could save many a company *up to £2,000 a year!* Why not call in Simmonds to carry out a completely thorough costing of your present assembly methods? *Our 16mm Nyloc colour film is available for showing in your factory.*

time saved is money saved **SIMMONDS SELF-LOCKING NUTS**

* *All times shown are based on "The Handbook of Standard Time Data for Machine Shops" by Haddon & Genger, published by Thames & Hudson Limited, London.*

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Flash Welding . . .

Extraordinary . . .

. . . up to 15 sq. ins. in Mild Steel, 6 sq. ins. in Titanium Alloys: up to 5 sq. ins. in "Nimonic" 75 and 2 sq. ins. in "Nimonic" 90! Complete uniformity of weld quality and accurate tolerances minimise machining and improve yield. Reynolds Flash Welding facilities include machines of up to 60 tons upset capacity.

Write for full details.

REYNOLDS

REYNOLDS TUBE CO. LTD. · TYSELEY BIRMINGHAM 11 E.13.

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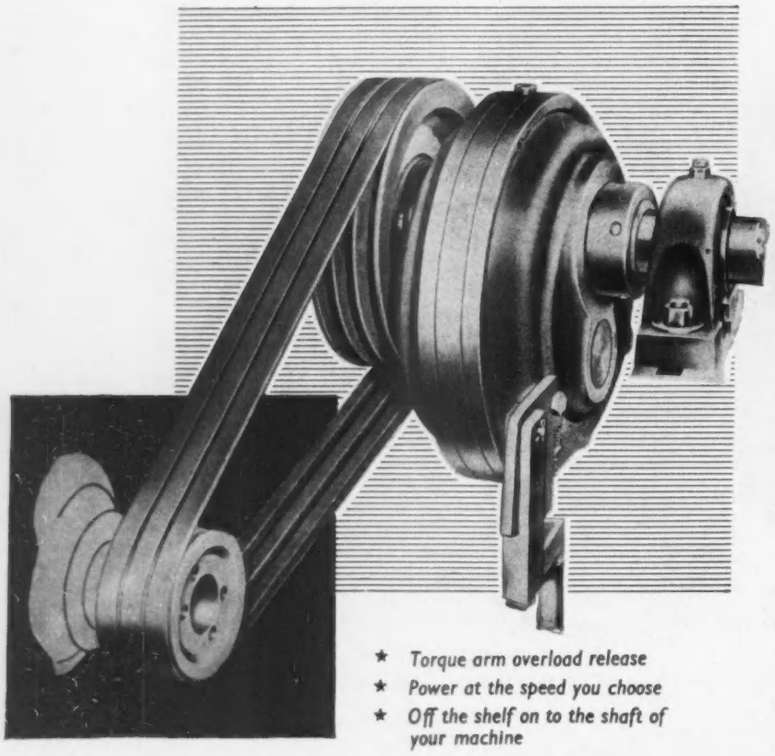

★ *Torque arm overload release*
★ *Power at the speed you choose*
★ *Off the shelf on to the shaft of your machine*

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The Ampulco "SHAFT-KING"

SPEED REDUCTION DRIVE

THE MOST ADVANCED UNIT AVAILABLE TODAY

"Shaft-King" is a new Speed Reduction Drive consisting of a compact reduction gear unit mounted on the shaft extension of the driven machine by means of a keyed tapered bushing. It is round like a gear or sprocket and no larger and not much heavier. Connected by a short centre V-Belt drive from the input shaft to a motor of any make or type.

The most important feature of "Shaft-King" is the concentric shaft design which with the overload release torque arm guarantees complete protection against sudden shock loads.

"Shaft-Kings" are made in 3 sizes for ¼ to 12 H.P. in two ratios 13:1 and 20:1. Other sizes will be available shortly.

"Shaft-Kings" are space saving, economical, easy to select and easy to instal. Please write for further particulars.

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'HARCO' CLOTHES LOCKERS

These are of open wire mesh on stout steel frames, providing security for personal property whilst allowing filtered air to circulate freely through the clothes.
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WW/10

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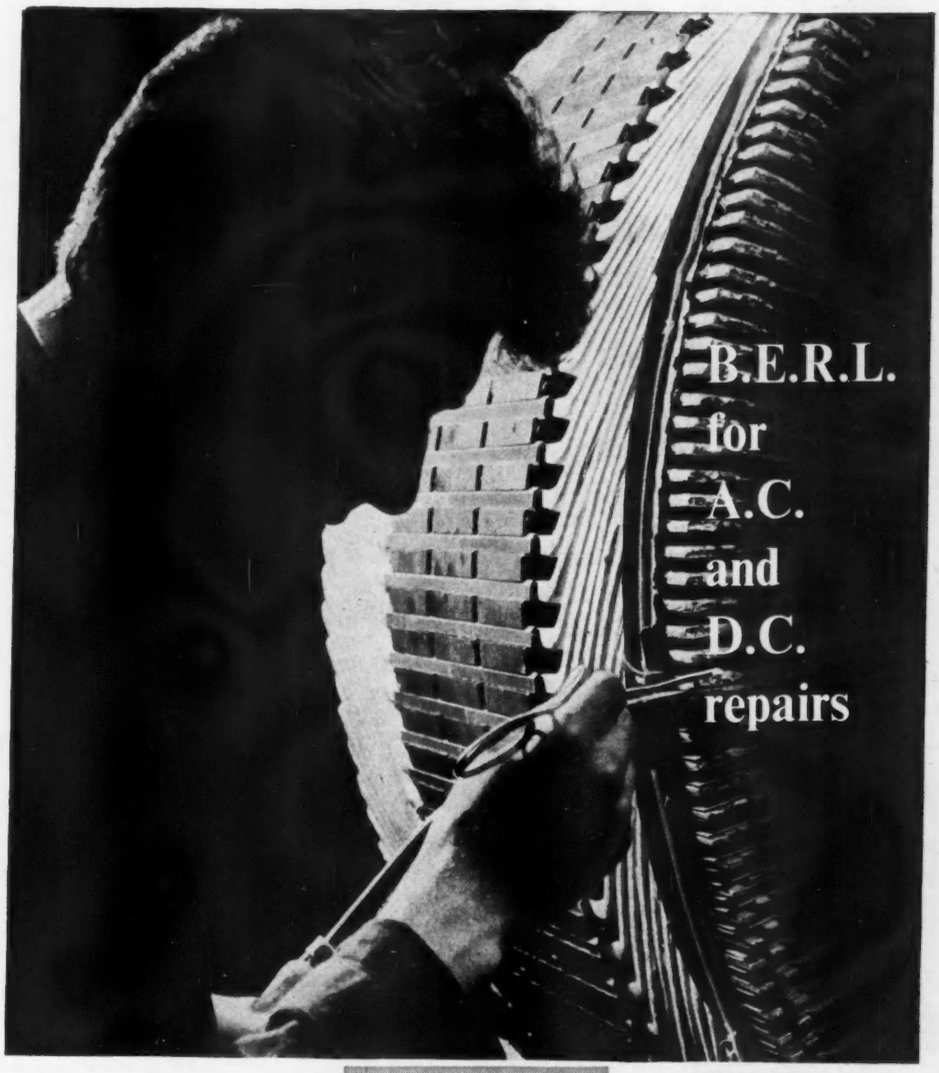

The illustration shows the soldering of the winding to commutator risers of a 1250 kW., D.C. generator armature

Works at: Bath, Birmingham, Cardiff, Chesterfield, Edinburgh, Glasgow, Hawick, London, Newcastle, Swansea

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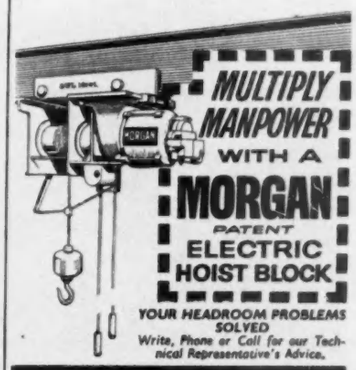

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In ¼" to ½" thick Mild Steel

PRESSURE VESSELS
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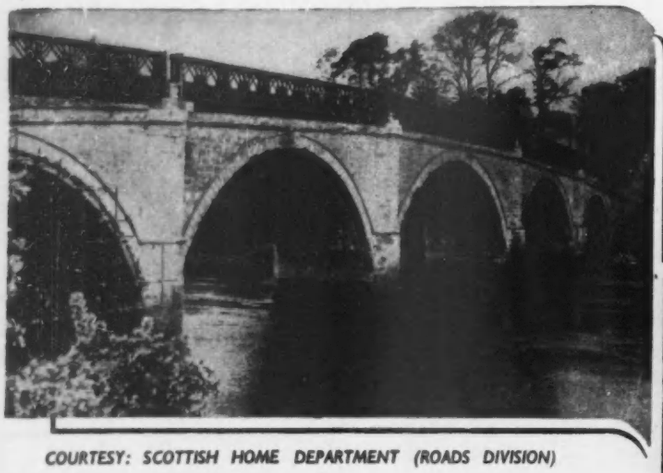
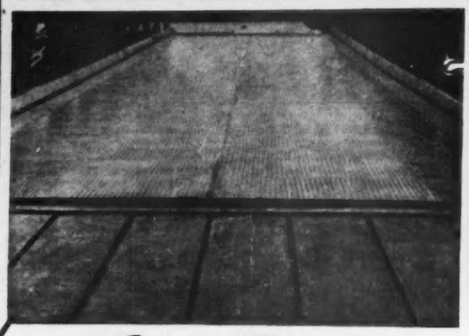


COURTESY: SCOTTISH HOME DEPARTMENT (ROADS DIVISION)

Bailey Bridges the Gap...



...on a Trunk Road in Scotland

With the increase in weight of modern traffic, many of the older type of bridges may require to be strengthened, particularly in order to carry abnormal indivisible loads. In this particular project a Bailey Bridge is erected on the existing stone piers and decked with Storey Steel Decking which is asphalt carpeted.

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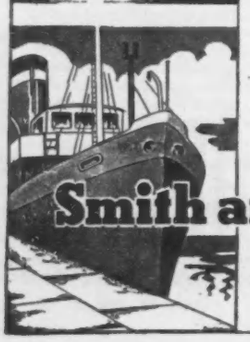

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This is a better LUG-TYPE COUPLING for SUCTION and DELIVERY HOSE

In best quality brass, gun-metal or stainless steel. Lugs are buttressed for extra strength. Washers cannot fall out. Screwed B.S.P. threads (Special threads to order). Specially selected leather washers. Machined and polished all over.

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THE "HERCULES" RANGE INCLUDES ALL TYPES OF HOSE FITTINGS:

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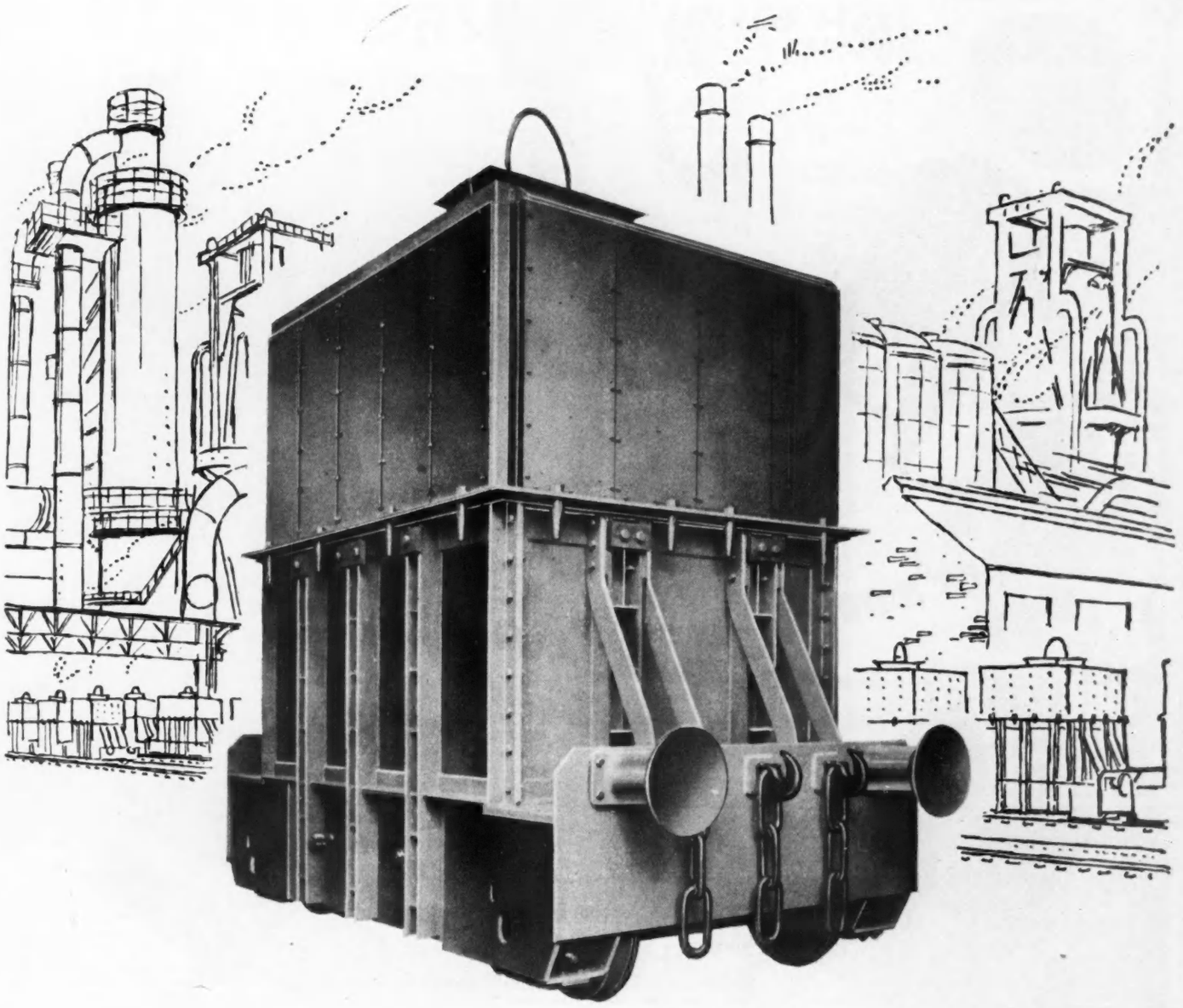

another THORNTON contract

This Insulated Transfer Car is one from a large contract recently supplied to Messrs. Colvilles Ltd. They are fitted with removable covers and insulated for conveying two 20 ton hot ingots. The Transfer Cars are made to suit British Railways standard gauge.

If it's a heavy engineering contract—try Thornton's first!

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there's nothing we can't 'tailor' for you!

From air receivers to fractionating columns . . . from bedplates to steel towers . . . in fact, almost every type of welded vessel and fabricated plant in industrial use today falls within the productive capacity of RUSTON 'tailors in metal.' Superiority in quality and maximum efficiency in operation . . . these vital factors are guaranteed by RUSTON, the manufacturing engineers with advanced production facilities and vast experience in 'tailoring' in metal.

RUSTON welded vessels and industrial plant

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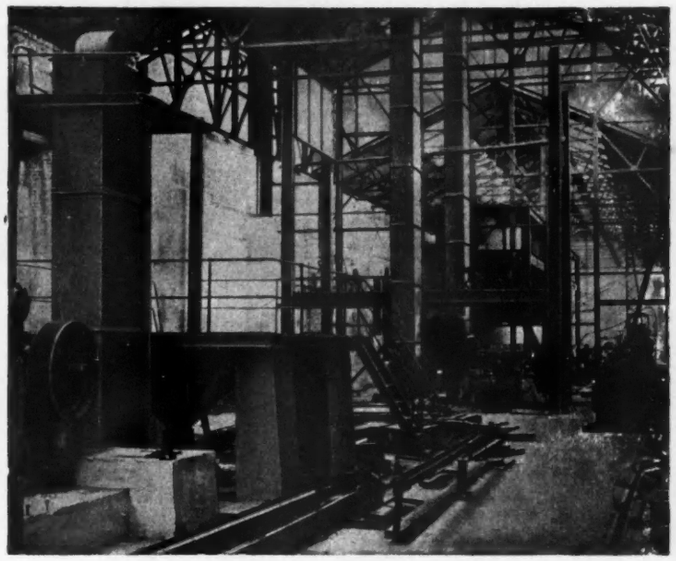

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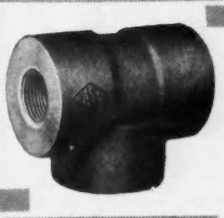
Screwed A.P.I., B.S.T.P.T. or socket weld. Materials: Carbon steel, chrome-molybdenum or stainless steel.



C.W.P. non-shock
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3000 lbs series
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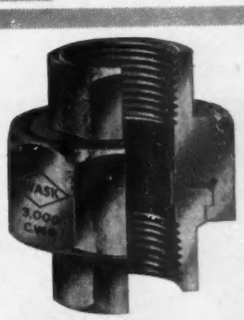

FORGED STEEL UNIONS

Integral seats or inserted stainless steel, chrome-molybdenum or bronze.

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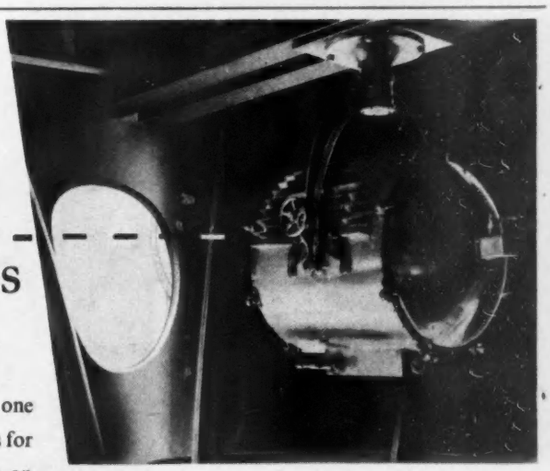
Spotlight on Specials



The "British Duchess," one of the new 42,000 tonners for BP Tanker Co., carries an L.E.F. "Suez" searchlight. This type of searchlight, regularly supplied to vessels of the BP, Shell and Esso Fleets, has been specially designed for tankers.

In the "British Duchess" installation the searchlight is permanently mounted, inverted on runners, below deck, moving forward to a specially constructed porthole when required. After use it is run back to the stowing position.

There is an L.E.F. searchlight for every type of vessel—large or small and if you have a particular problem, London Electric Firm can design a searchlight to fit the bill.

A catalogue of L.E.F. standard searchlights is available on request.

L.E.F. SEARCHLIGHTS
are designed and manufactured by:
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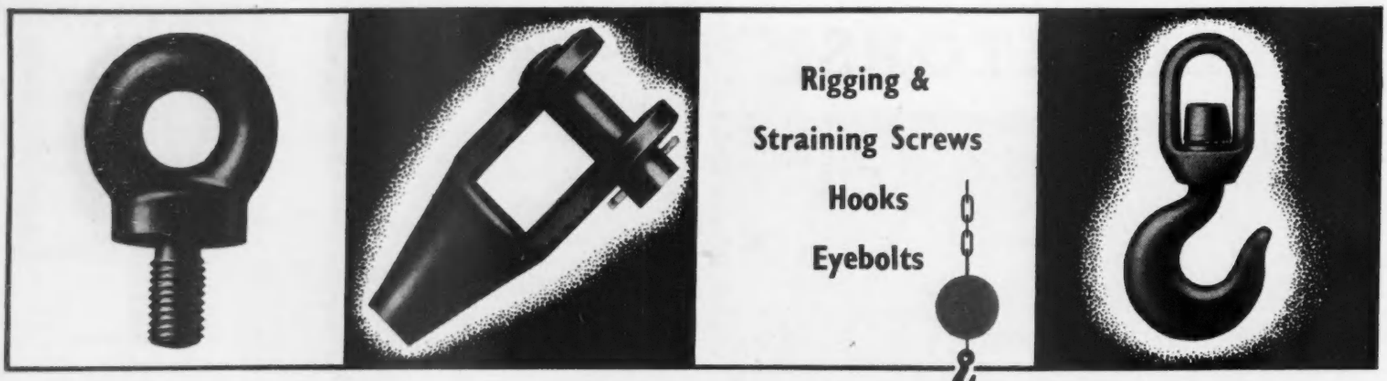

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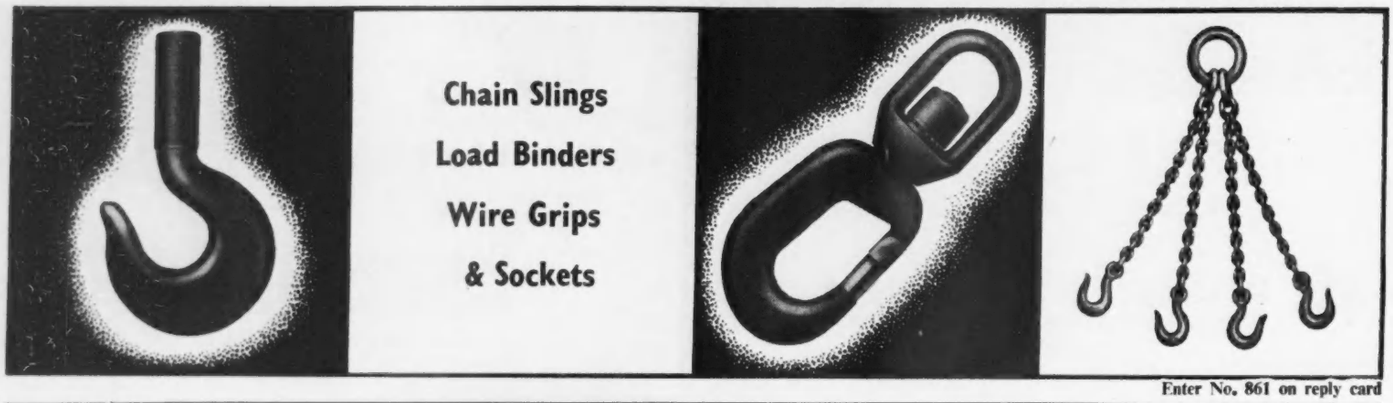

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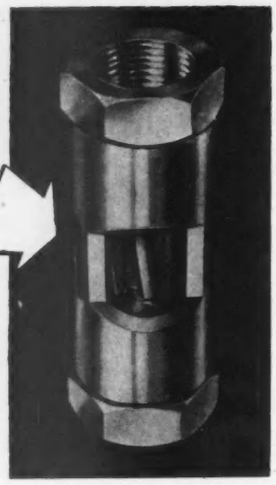
See

the flow with the 'Telicator'



Both low and high pressure systems can be fitted with a Telicator Visual Flow Indicator, which is a simple instrument for indicating the flow, whatever the viscosity. The rotors are specially designed by Dukes and Briggs to give the clearest indications over specific ranges of flow rate. Water supplies for cooling purposes and forced lubrication systems are two typical applications. A new model is under development for use with opaque fluids, and special designs can be made to meet specific requirements.

Note these features

- *Simple design ensures complete reliability.*
- *Extreme sensitivity at all pressures.*
- *Units readily adaptable to existing installations.*
- *May be mounted in any plane.*
- *Comparative flow gauged by speed of revolving rotor.*

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What it does . . .

It cleans all scale in a period of about 3 months and thereafter positively prevents any scale formation whatsoever. It results in chemically pure (pH-7) steam and no component of the liquid can be detected in the condensate, which will be free from odour or taste.

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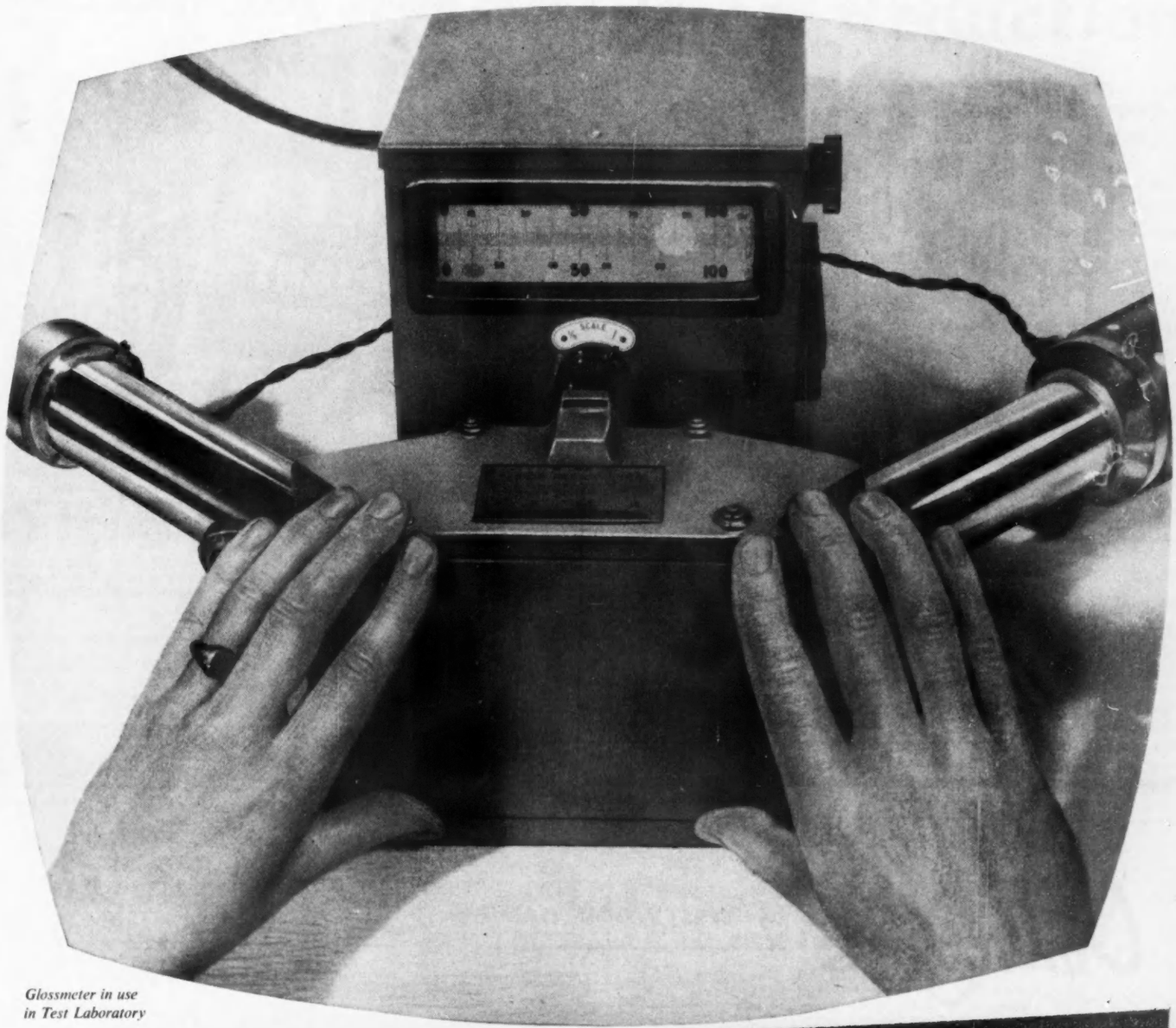

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Each batch of paint has to pass rigorous inspection in the Pinchin Johnson test laboratories, before dispatch. This is just a part of the service available to you through the P.J. technical representative from your nearest branch.

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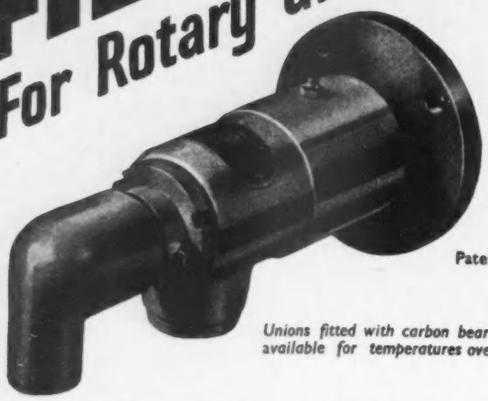
Consult
FILTON
For Rotary Unions—



Patented

Unions fitted with carbon bearings are available for temperatures over 400° F

For use on all types of Rotary and Semi-Rotary machines for Leakproof Fluid Transfer.
Standard Sizes ¼"—3" B.S.P.
Special Sizes & Designs up to 6" B.S.P.

(TYPICAL EXAMPLE SHEWN ABOVE)

As used by leading Engineering Companies and Government Departments

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keep works maintenance up to the mark with a

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HALF-BAG
'MINI-GIANT'
4/3 CU FT CAPACITY MIXER

Simple to use.
Easily handled by one man.
Goes through a 2' 6" doorway.
Mixes concrete, tarmacadam, mortar and plaster.

Saves time and labour, cuts out costly hand mixing on car park and path surfacing, machine beds and machine shop floor laying.

Standard side or end discharge models with cushioned rubber tyres and 1 h.p. petrol engine—£86. Electric motor available. Hire purchase terms £8 12 0 down and twelve monthly payments of £6 18 1.

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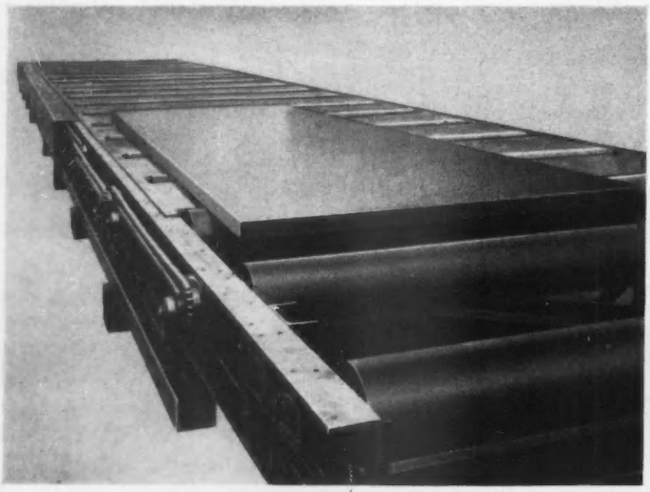
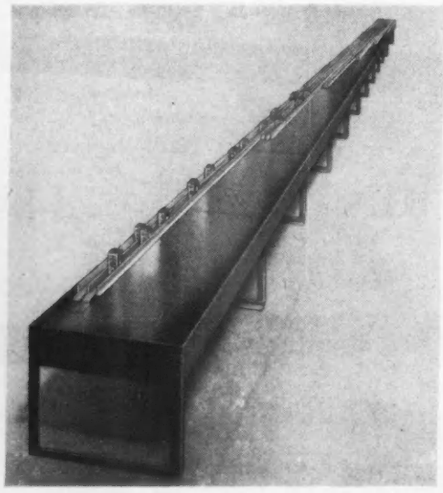
Conveyors
by WESTWOOD DAWES

Ten Tons of Steel! OR A Quarter of Tea AND MOST THINGS IN BETWEEN!





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WESTWOOD DAWES

Troughed Belt Conveyors
Flat Belt Conveyors
Slat Conveyors
Scraper Conveyors
Gravity Roller Conveyors
Powered Roller Conveyors
Elevators, etc. etc.

WD

These photographs give an idea of the wide range of our products and the variety of applications for which they are specially designed.
Left: A heavy duty, powered roller conveyor carrying 2in. thick steel plates. *Right:* A 100ft long conveyor with twelve separate belts carrying ¼ lb. packets of tea.

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7½%

FROM THE STANDARD LIST PRICES OF

Oldbury Chain Grate Stokers

ordered in the twelve months commencing 1st November 1959. Hire purchase terms are available from that date.

This offer is made in recognition of the national importance of maintaining a healthy coal industry and in support of the National Coal Board Campaign.

Proved by 17 years' successful operation, the Oldbury Stoker endorses the claim of the National Coal Board that coal, the home produced fuel, is competitive in price and performance with other fuels.

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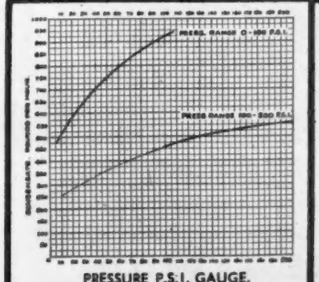

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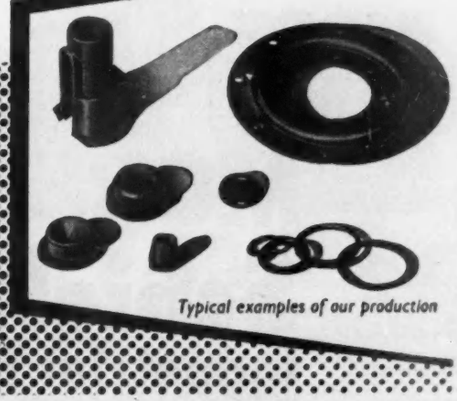

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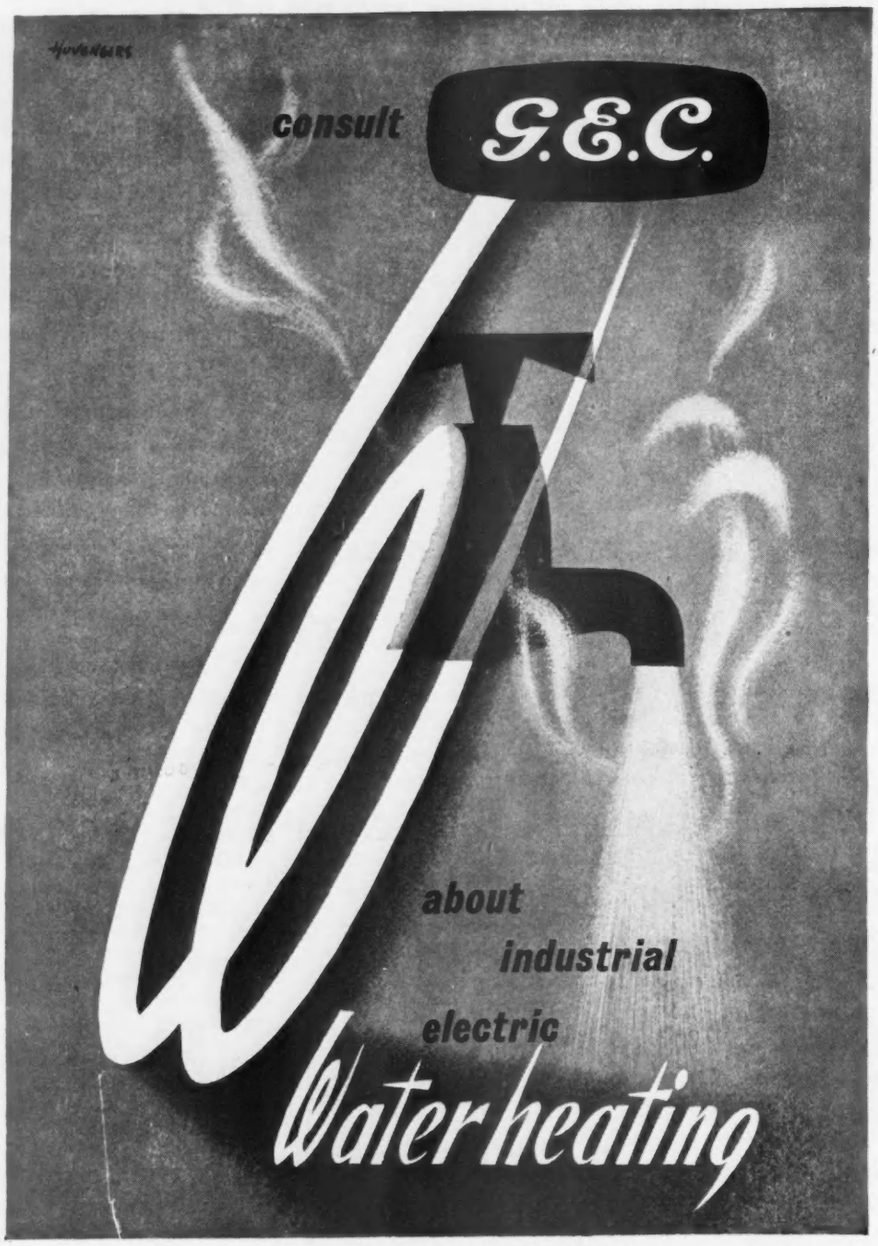

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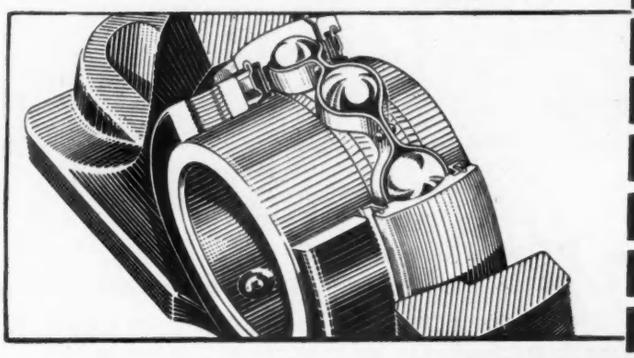

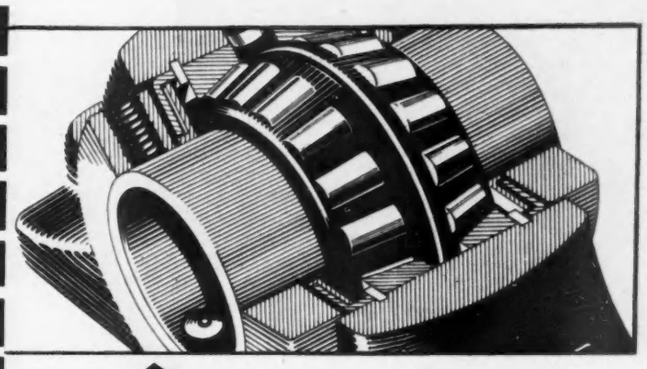

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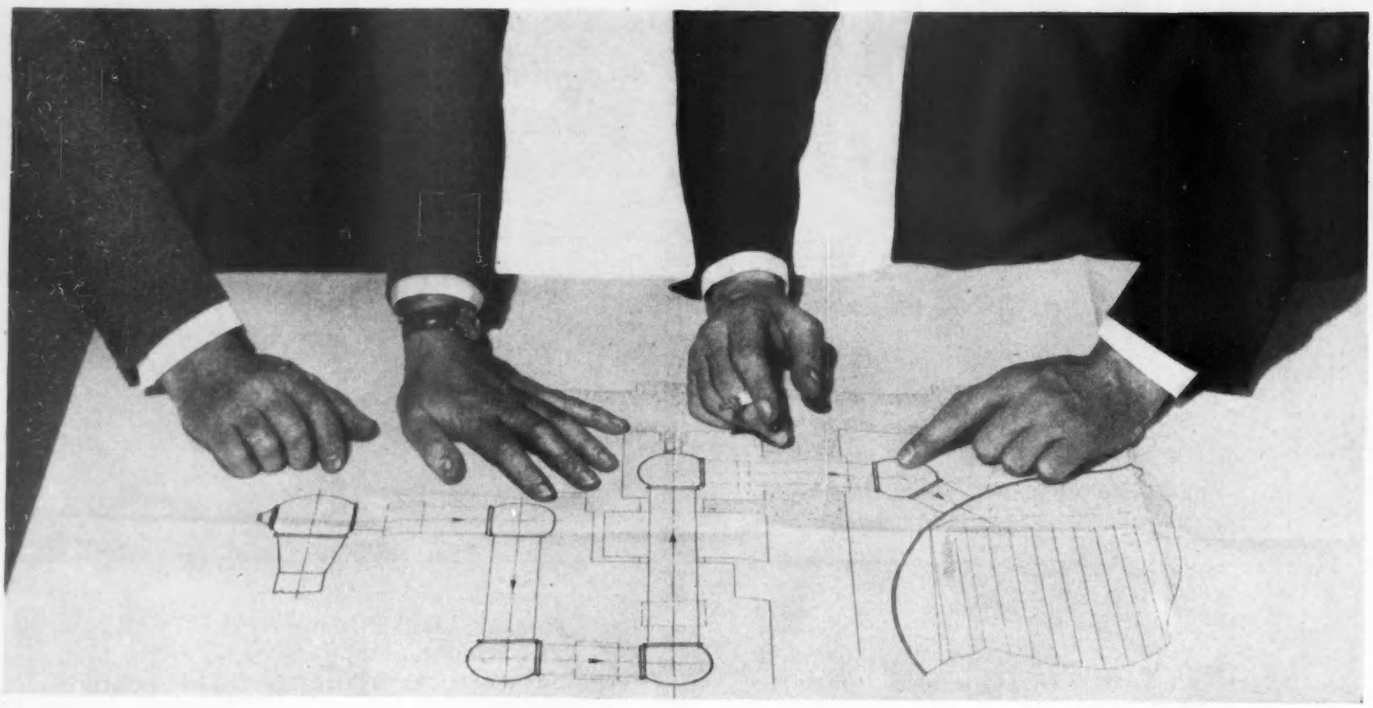

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We spread out the drawings . . . an instant of surprised silence; then that gratifying sound. It is usually something like "Of course! Why didn't somebody think of that before."

Why not indeed? All we have done is to make the bends in the CO_2 pipework of an atomic reactor, spherical. Any schoolboy with G.C.E. physics knows the formula for the thickness of a pressure vessel—

Cylindrical: $t=\frac{P.R.}{S}$ Spherical: $t=\frac{1}{2}\frac{P.R.}{S}$

So with a sphere you can halve the thickness of the plate. But that is only the beginning. Bonuses roll in. All welds become circular, can be made by machine and can be X-rayed easily and completely. There are no uncertainties—no stiffening webs, for instance, attached by welds which cannot be X-rayed. The guide vanes are part of a lightweight duct, inside the sphere and thus unstressed by pressure.

A simple and indeed an obvious idea; but it can save large sums of money on the cost of a power station or a wind tunnel. The fact is it is not easy to see the obvious; the orthodox approach, the standard answer, get in the way. However, some of our engineers seem to be able to do it, thank goodness.

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RWG

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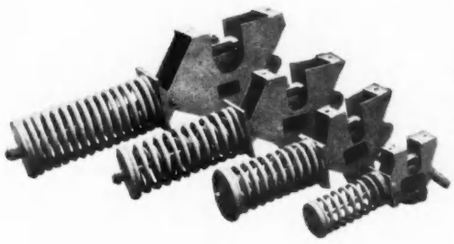
Wife, three children and 584ft of piping to support

And if he is as devoted to his job as he is to his family he will ask VokesGenspring to help him with the pipe support problem. The new 'M' range hangers are the result of long practical experience and field research. They are designed to provide a constant support for high temperature pipework over a wide range of vertical movement, thereby eliminating the dangers of increased stresses in the system and consequent joint failures and other troubles.

To ensure accurate loading over the full range including overload, every Genspring is individually checked on one of our special test rigs for which the strain gauges were calibrated by the National Physical Laboratory. *Maximum deviation can now be guaranteed at not more than 2% if required.* Test Certificates are available at time of dispatch and revised settings will be supplied if further adjustment on site is required; this adjustment can be up to 20% of rated load.

Please write for catalogue covering the 'M' range Constant Support Hangers. Load and travel characteristics are tabulated in this booklet together with much additional information including a section on determining hanger loads.



M1 to M4 Constant Supports covering loads from 315 lb. to 22,500 lb. and travels from 1.5" to 12". The latest addition to the range is Type M7 for loads up to 97,800 lb.

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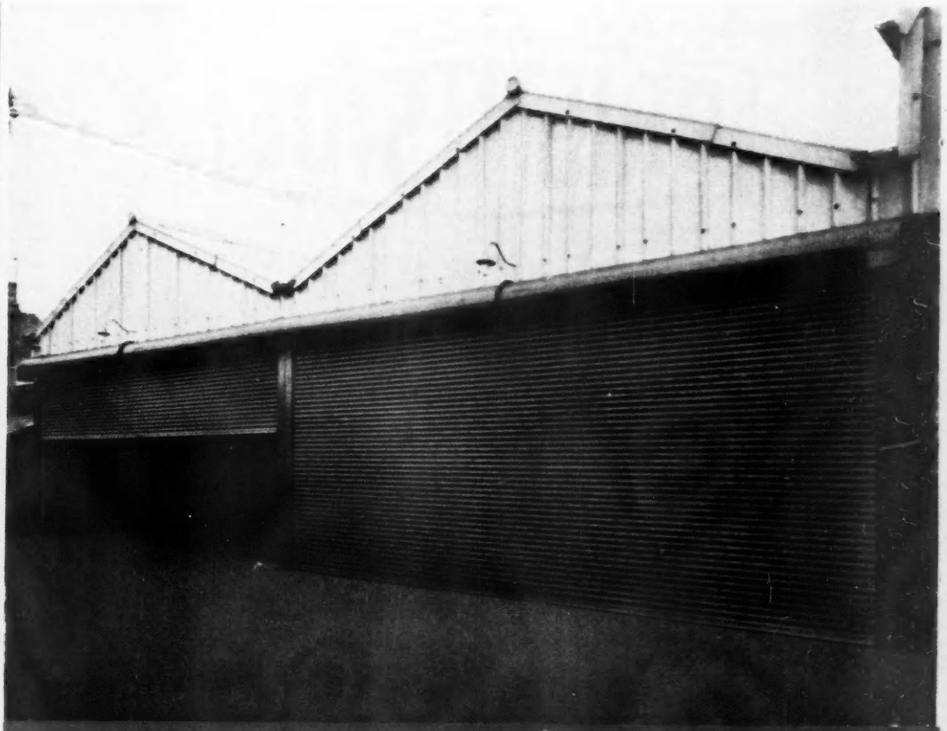

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A If you are worried about the payroll and your mind jumps to the kind of gentleman shown above — ask a policeman.

If you are thinking of circuit-breakers—the J. & P. Type PDB arc-control oil circuit-breaker is undoubtedly the right answer.

This breaker achieved a remarkable performance during tests and, although designed for the more usual distribution duties of 250 MVA at 11 kV, it is certified for a breaking capacity of 350 MVA at 11 kV — a margin every engineer will appreciate is safe.

The TYPE PDB OIL CIRCUIT-BREAKER

- ★ **has certified breaking capacities of**
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- ★ **has current ratings of 400A, 800A and 1200A.**
- ★ **is designed for use in standard metalclad gear only 1′ 9½″ wide.**
- ★ **is available at very competitive prices.**
- ★ **has had each phase successfully tested to earth separately at full power.**
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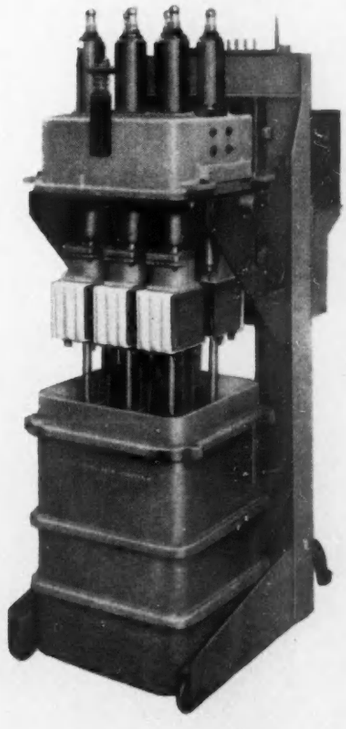

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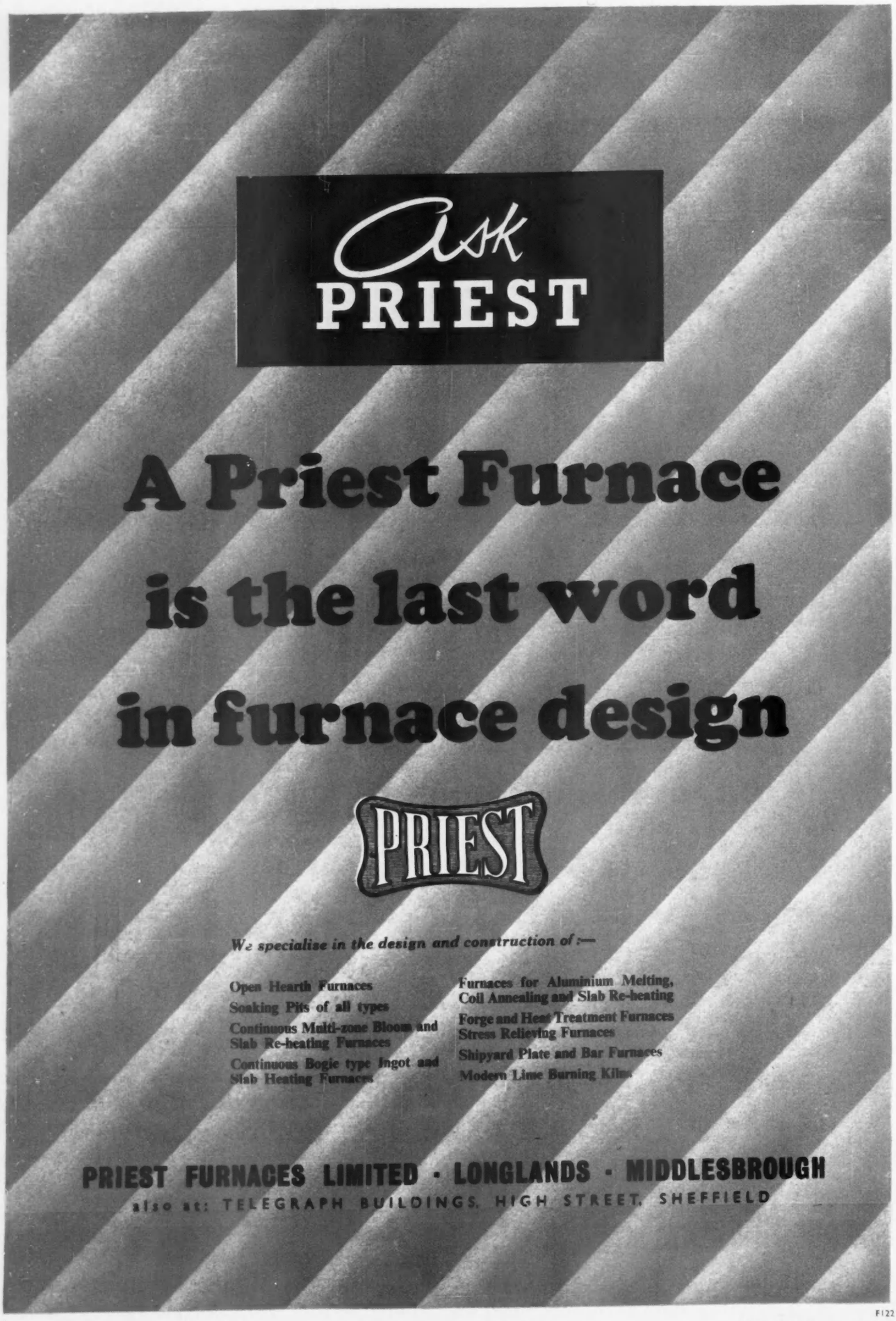
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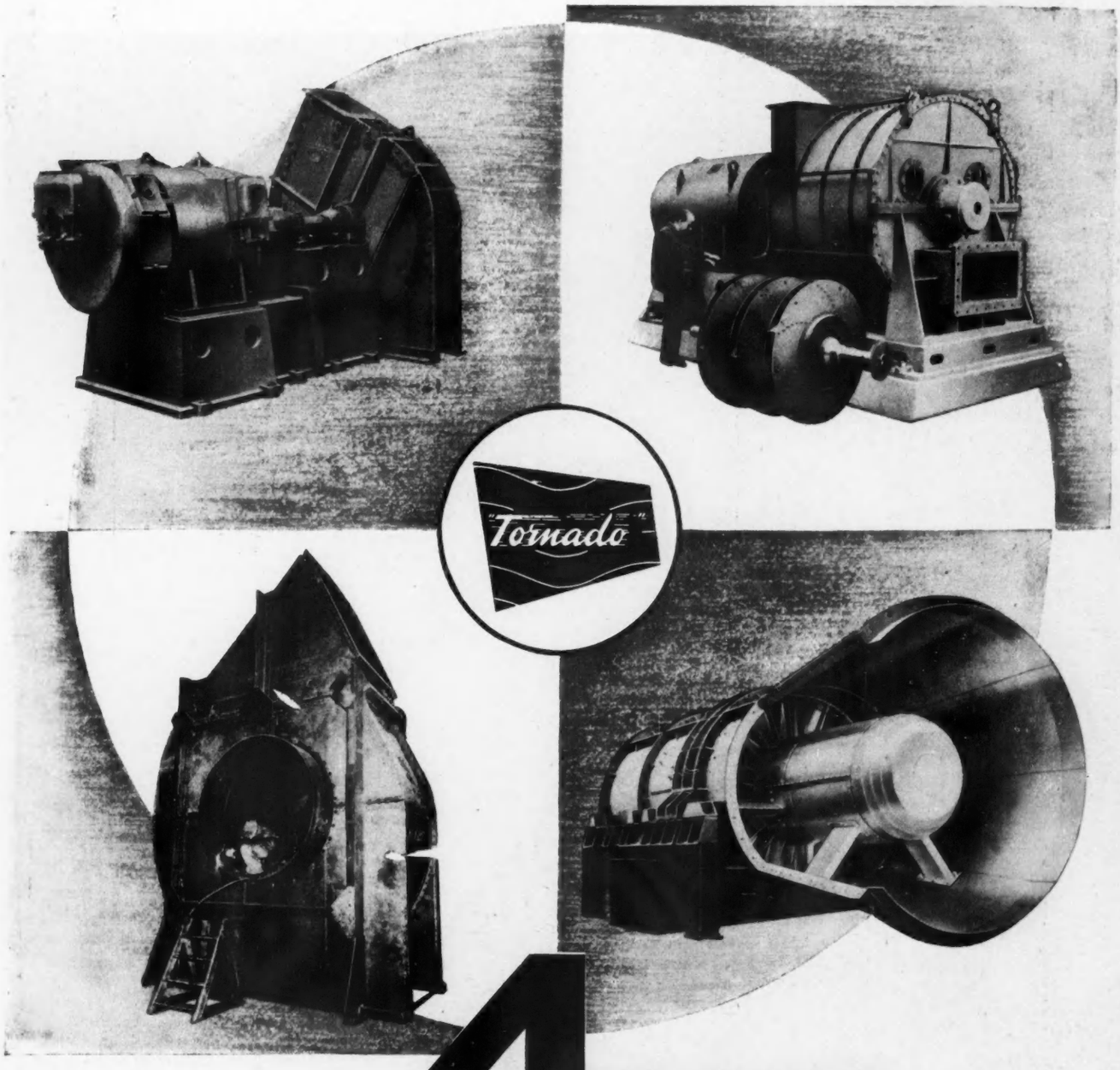

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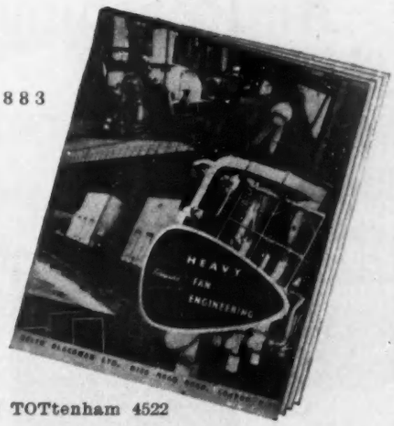

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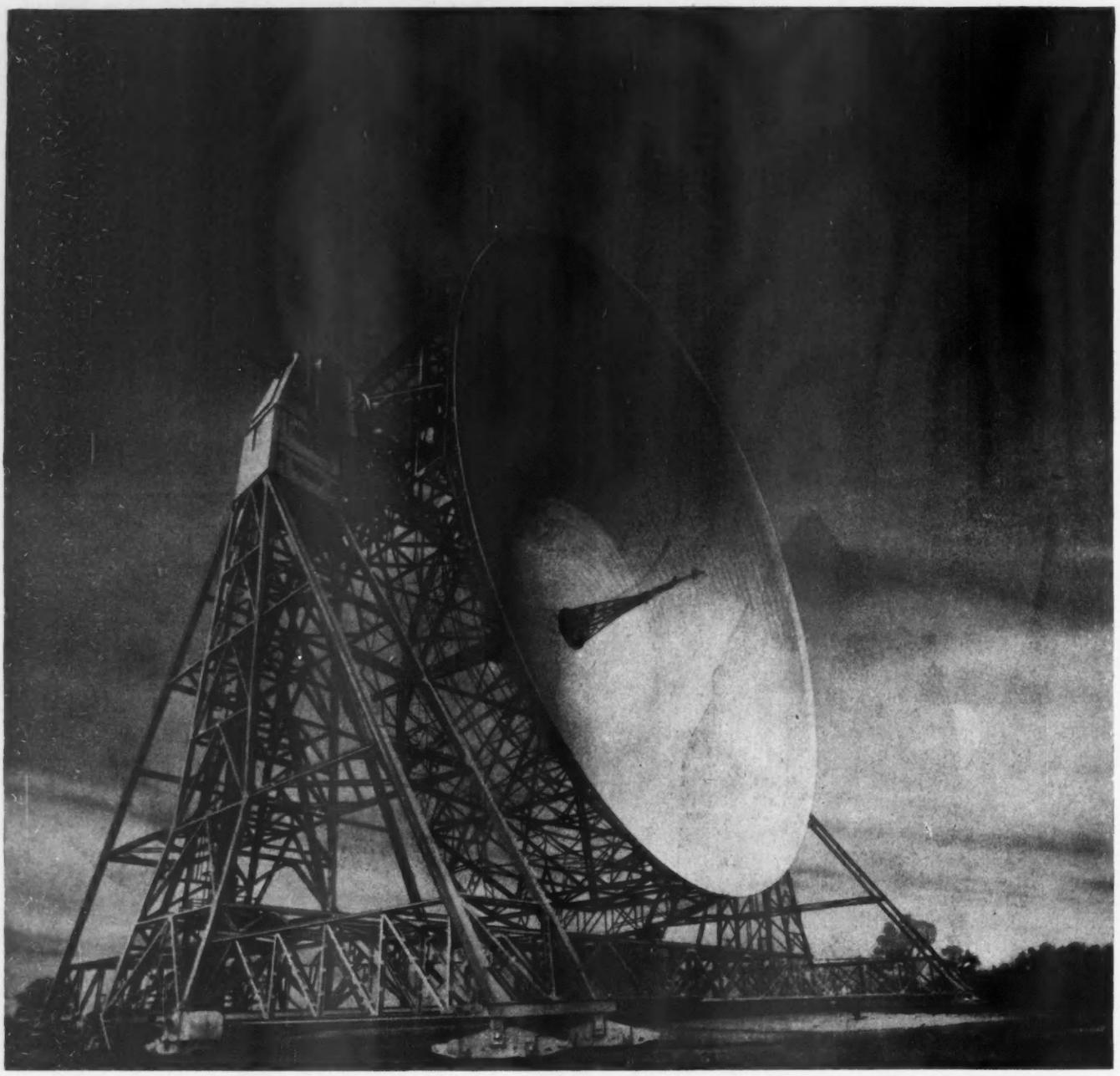

Acknowledgments to Husband & Co., Consulting Engineers, and to The United Steel Companies Ltd.

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Mankind has for ever been reaching for the stars, and today space travel is fast being transformed from a dream into a practical reality. The great radio telescope at Jodrell Bank, which provides a vital link between the earth and space satellites, is making an all important contribution to man's knowledge of the universe. This vast steel structure is the largest steerable radio telescope in the world and it represents one of Britain's finest engineering achievements. It was designed and constructed by British engineers and the bowl was exclusively welded with Murex "Fastex 5" and "Ironex 5" electrodes, while the trunnions were welded with Murex "Fortrex 35" electrodes. These electrodes are at your service.

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This by-pass filter fulfils the vital function of removing ultra-fine peptised carbonaceous matter which tends to clog and impair the efficiency of the full-flow filter.

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The Micro-Pak is available in a range of capacities, with centre-bolt or multi-bolt head, and either heated or unheated.

The multi-bolt unheated model is illustrated in cut-away form.

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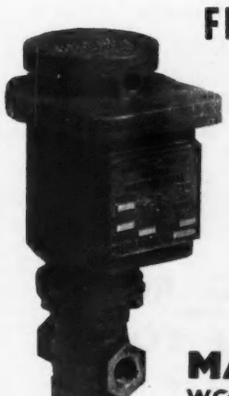

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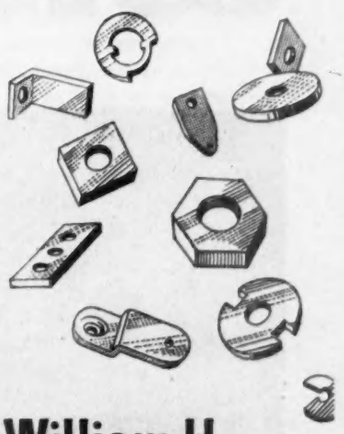

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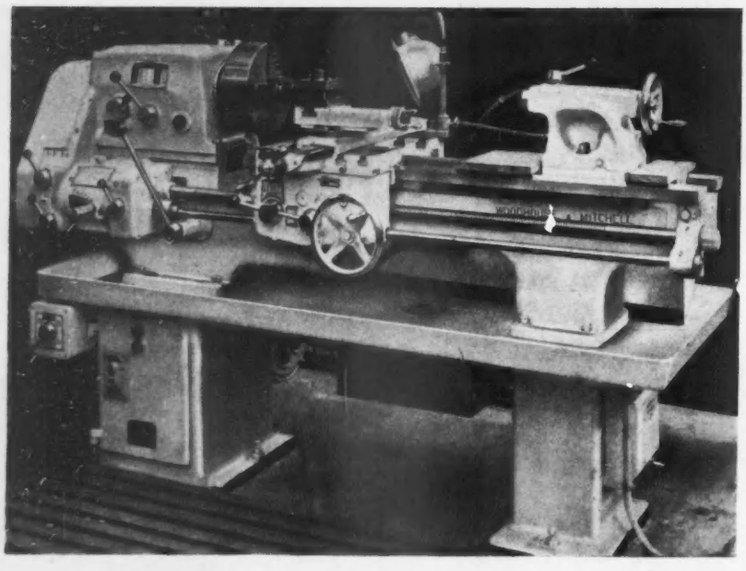

Stand No. 54 at the Machine Tool Exhibition, Olympia, in June.

In their maintenance shop at London Airport B.O.A.C. have a number of WM Lathes, both Series 85 and 70 Junior. These are engaged on high grade precision work, and it is due to the most satisfactory experience of these tools in production that B.O.A.C. have periodically added to their complement of WM Machines.

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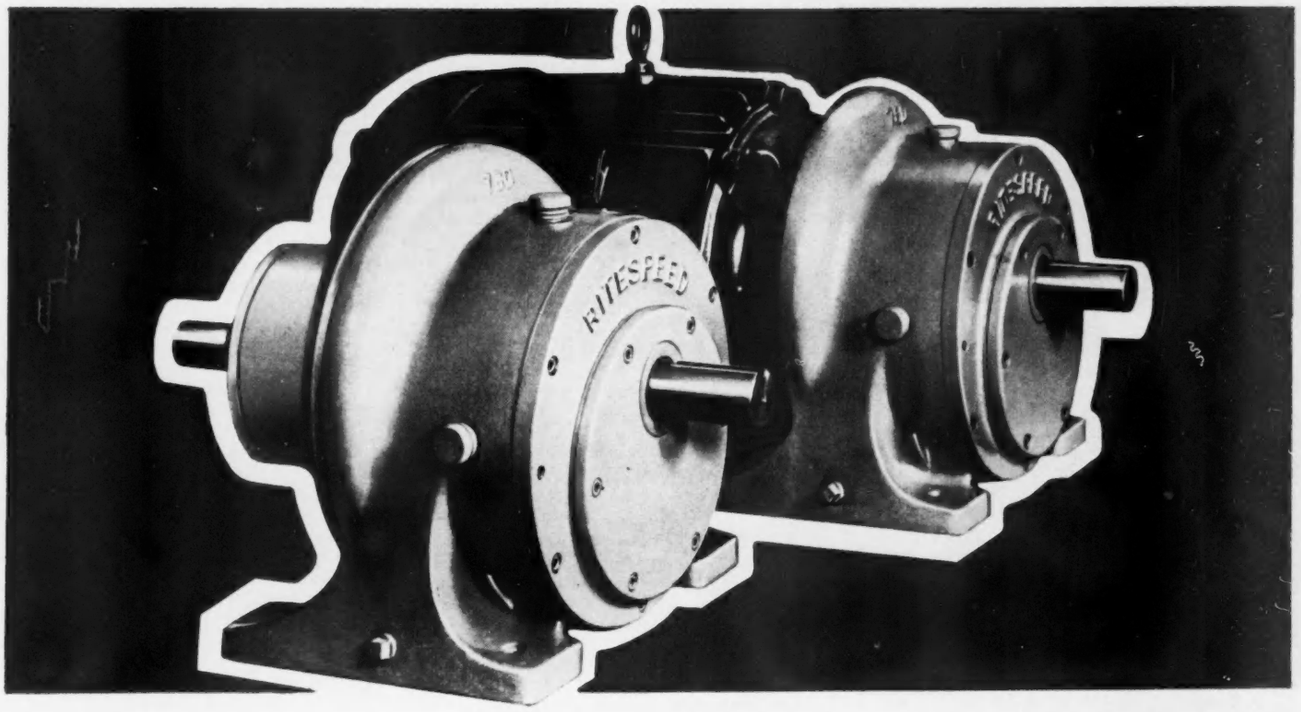

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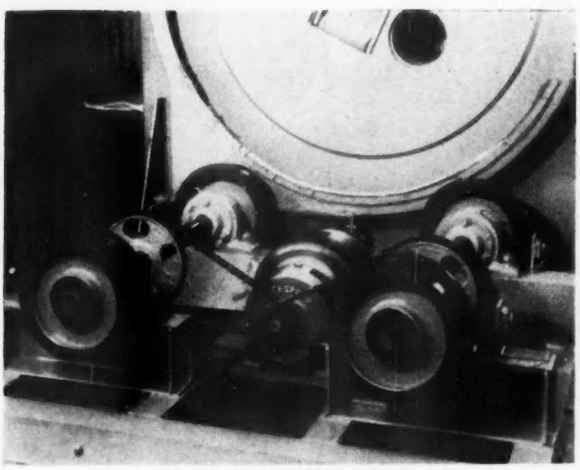

A Tumbling Barrel driven by a 'Ritespeed' Geared Motor and chain drive.

'Ritespeed' is the name given to the well-known range of Spur Reduction Gears and Geared Motors produced by Crofts of Bradford.

Compact in design, they can be mounted in any position, and there is a Flange-Mounted Series, including Vertical Geared Motors for use with stirrers, mixers, and similar machines.

Gear cases are made from Crofts semi-steel, a tough, durable, close-grained metal, and the gears are accurately machined from high-tensile steel bars or forgings dependent on the size of the unit.

The Geared Motors and Reduction Gears cover the same power range, the former taking any make or type of flange-mounting electric motor.

In addition, the incorporation of a HIRATIO adaptor enables ratios up to 2175:1 to be obtained, while the inclusion of a MULTISPEED unit provides two, three, or four speed changes, selected by hand lever.

"Ritespeed" Geared Motors and Reduction Gears can be supplied from fractional up to 80 H.P. Ratios up to 82 : 1. Up to 20 H.P. supplied FROM STOCK.

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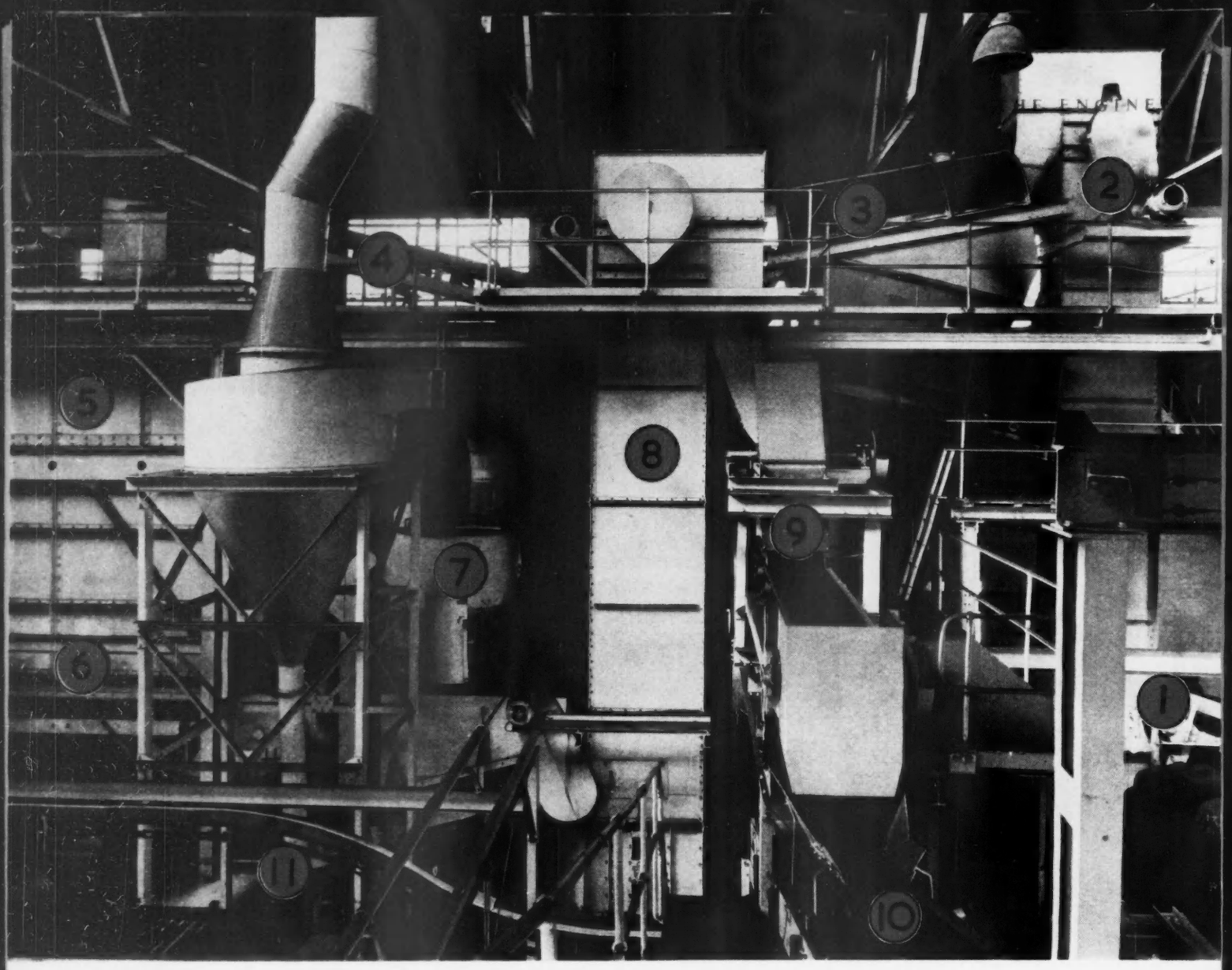

The illustration shows that part of a **MORRIS** foundry sand and mechanization plant which reconditions knocked-out sand. At **1**, sand coming from the knock-out via an apron plate and belt conveyor passes beneath a magnetic separator (to remove tramp iron) and falls into the boot of a belt-bucket elevator **2**, discharging into screen **3** onto belt conveyor **4**, which in turn discharges into sixty-ton storage hopper **5**. The flat belt conveyor **6**, under the hopper, pours sand into the skip which feeds the mulling machine (known as the Speedmullor). This machine **7**, providing a rapid mulling cycle with close batch control, discharges the sand into belt-bucket elevator **8**. From thence, the sand proceeds via belt conveyors **9** and **10** to the moulders. The overhead chain conveyor **11** serves the core shop with sand and also takes the cores to the stoves and to the moulders.

Consult MORRIS

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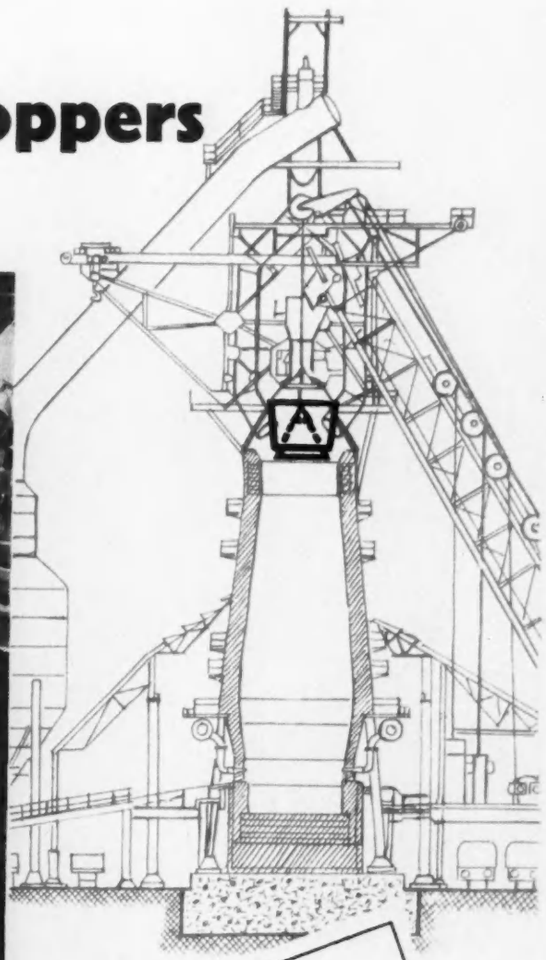

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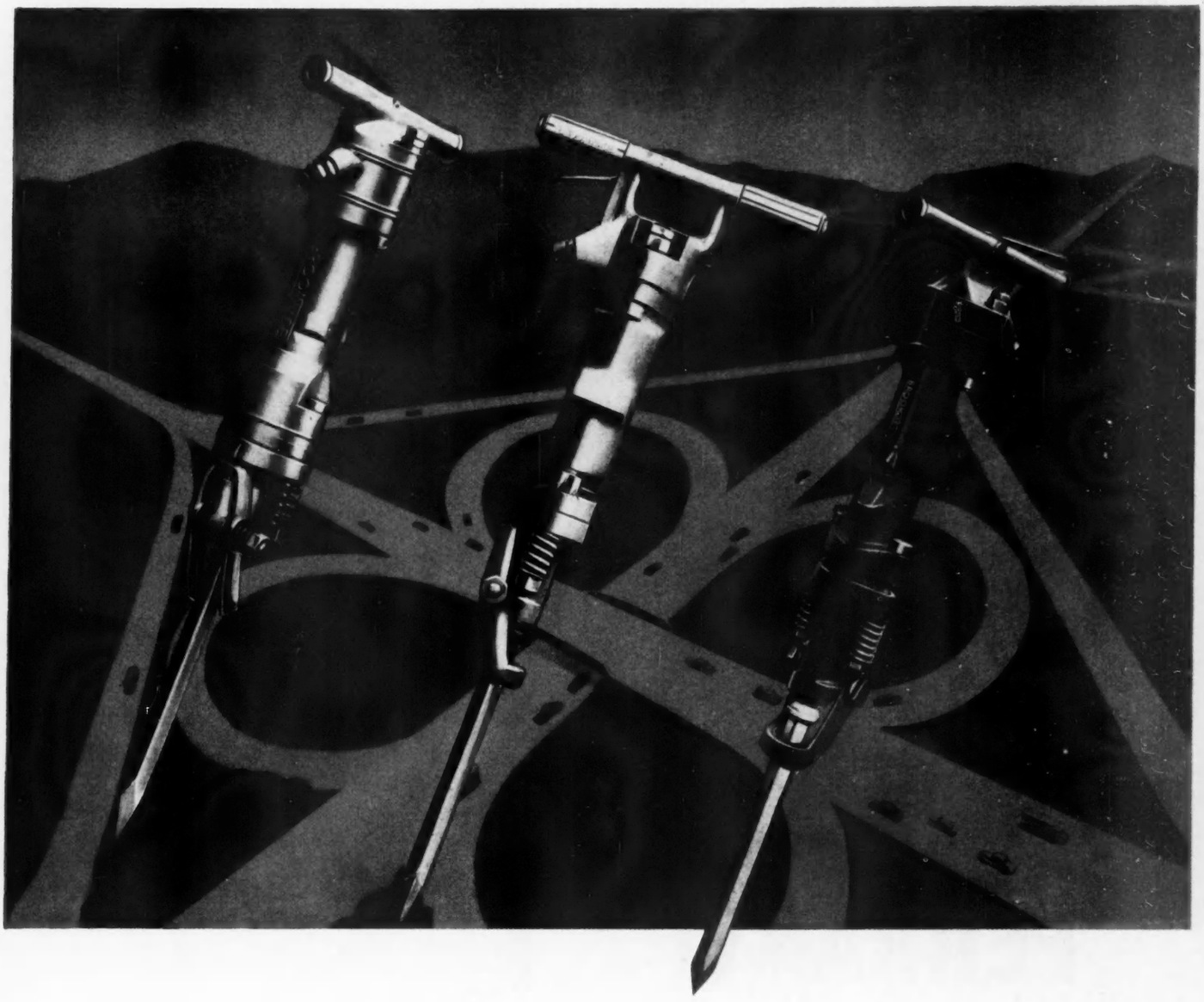

Breaking the Bottlenecks

By adopting the flyover bridge for roads which carry essential traffic up, over and away without loss of precious time, the road makers are tackling with energy and vision the problem of relieving traffic congestion. But however adequate the plans, it is necessary to have the right equipment.

Compressed air is being increasingly used and Pneumatic Tools are playing an important part, especially " BROOMWADE ", the demand for which is a tribute to excellence of design, workmanship, efficiency and reliability.

Illustrated (left to right) are : RB 770 B, RB 55 and RB 440 Road Breakers.

For full details write today for publication No. 401 T.E.

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OUTSTANDING FEATURES

- High speed resistor transition tap changing gear suitable for 3 phase circuits having a system high voltage of 37 kV r.m.s., on star or delta connected transformers.
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Penstocks for high capacity power schemes
Large size valves and gates for hydraulic plants
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Now there are 12

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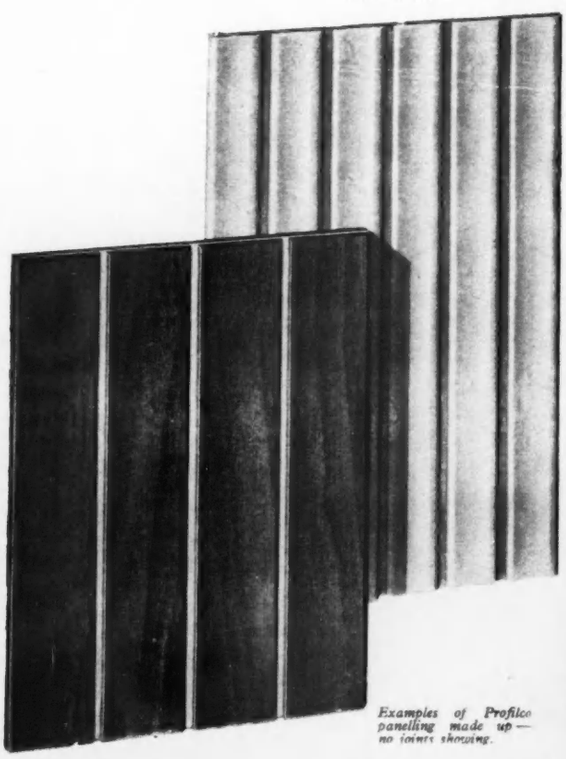
Distinctive panellings in decorative plywood

Below are actual-size sections, with alternative facings.

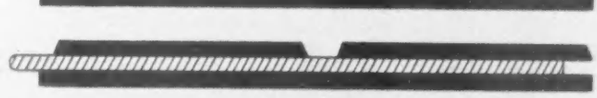


Examples of Profilco panelling made up — no joints showing.

Mahogany throughout 333.
Obeche face, Mahogany core 311.
Mahogany face, Obeche core 313.
96" long, 3¼" wide.

Obeche face, Mahogany core 315.
Mahogany face, Obeche core 317.
Mahogany throughout 334.
96" long, 3¼" wide.

Obeche face, Mahogany core 324.
Mahogany face, Obeche core 325.
Mahogany throughout 335.
96" long, 3¼" wide.



Obeche face, Mahogany core 326.
Mahogany face, Obeche core 327.
96" long, 3¼" wide.

Mahogany throughout 310.
96", 84", 72", 60" long, 24" wide.

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The first fabricated Hoist Tower to be produced in this country — especially designed to give the following advantages . . . .

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2. Designed for use by unskilled labour.
3. Possesses greater stability and strength.
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5. It is the COMPLETE answer and includes self-locating boards—wire mesh panels—manually operated gates at base—safety gates at working lift—and will suit any normal type of material hoist or small Passenger hoist. Full details from

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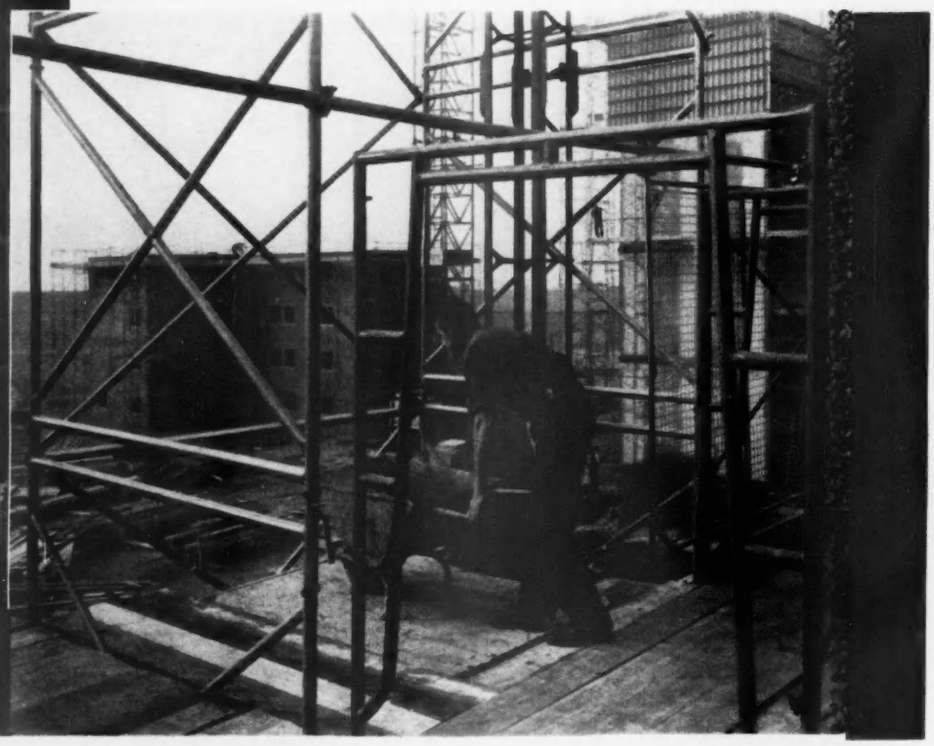
Tel. Bristol 39112.



597 Cogent

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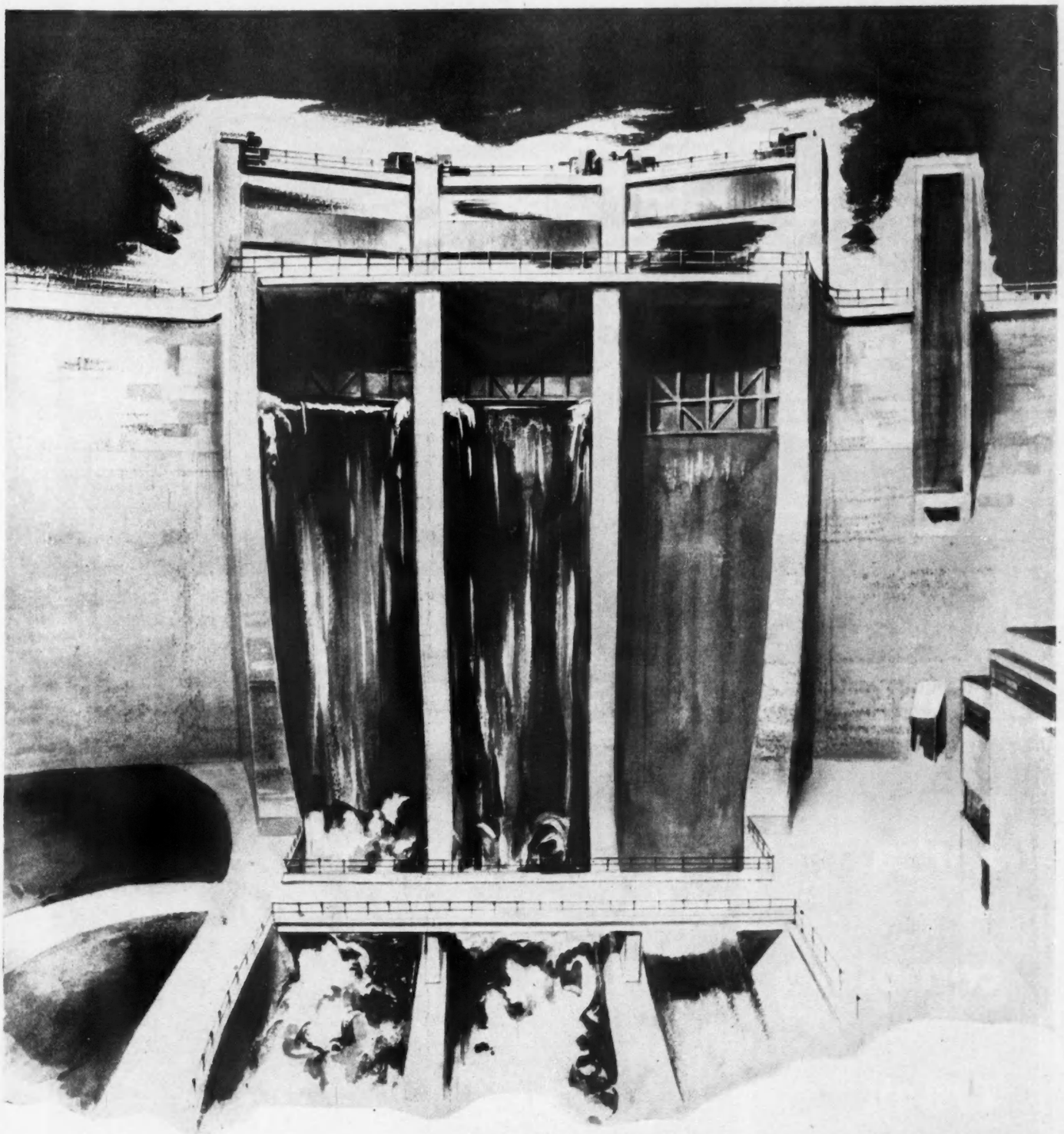

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AEI

Four AEI waterwheel alternators at the New Zealand Electricity Department's Roxburgh Power Station are already feeding 160,000 kW into the South Island grid. Four additional sets, to bring the station up to its designed capacity of 320,000 kW, are now in course of construction.

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MERCHANTS & SUPPLIERS • STOCKHOLDERS OF STRUCTURAL STEEL

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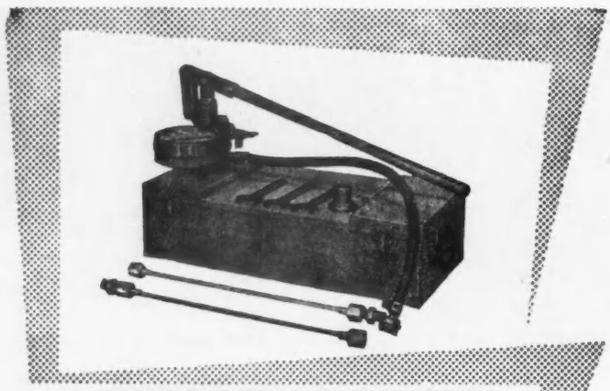

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Maximum pressures up to 10,000 lb/in.², with minimum of effort · Other models for lower maximum pressures · Supplied with strong wooden carrying box, on which pump is also mounted for use · Gunmetal and Steel construction · Can be supplied without boxes · Rubber suction hose with strainer · Copper delivery pipes with brazed-on connections.

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Eagre also works for British Railways, the Gas Board, the United Steel Companies, Central Electricity Authority, etc. Materials are supplied from Eagre's own resources.
Whatever the magnitude of your siding requirements, consult —

EAGRE CONSTRUCTION CO. LIMITED
East Common Lane SCUNTHORPE Lincs. *Telephone 4513 (5 lines)*

(Photograph by courtesy of the National Coal Board)

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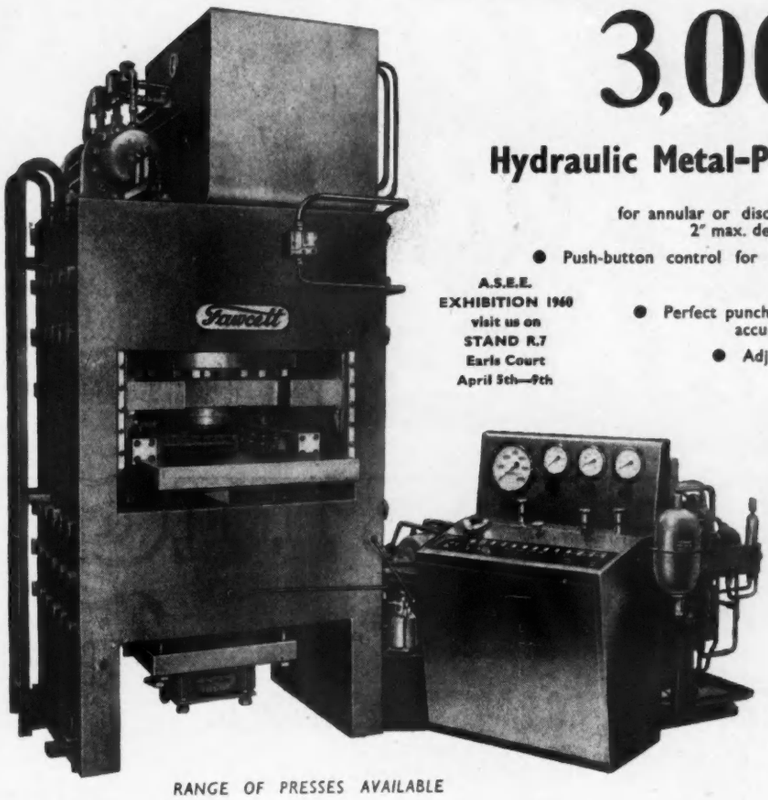

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Hydraulic Metal-Powder Compacting Press

for annular or disc-shaped components from 7" to 18" dia.
2" max. depth of die fill, or to your particular requirements.

- Push-button control for completely automatic or individual cycle operation.
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A.S.E.E. EXHIBITION 1960 visit us on STAND R.7 Earls Court April 5th—9th

Designed for the automatic high-speed production of repetition parts, Fawcett Hydraulic Metal-Powder Compacting Presses incorporate many new and exclusive features. We shall be pleased to send you details and to advise on YOUR particular production problem.

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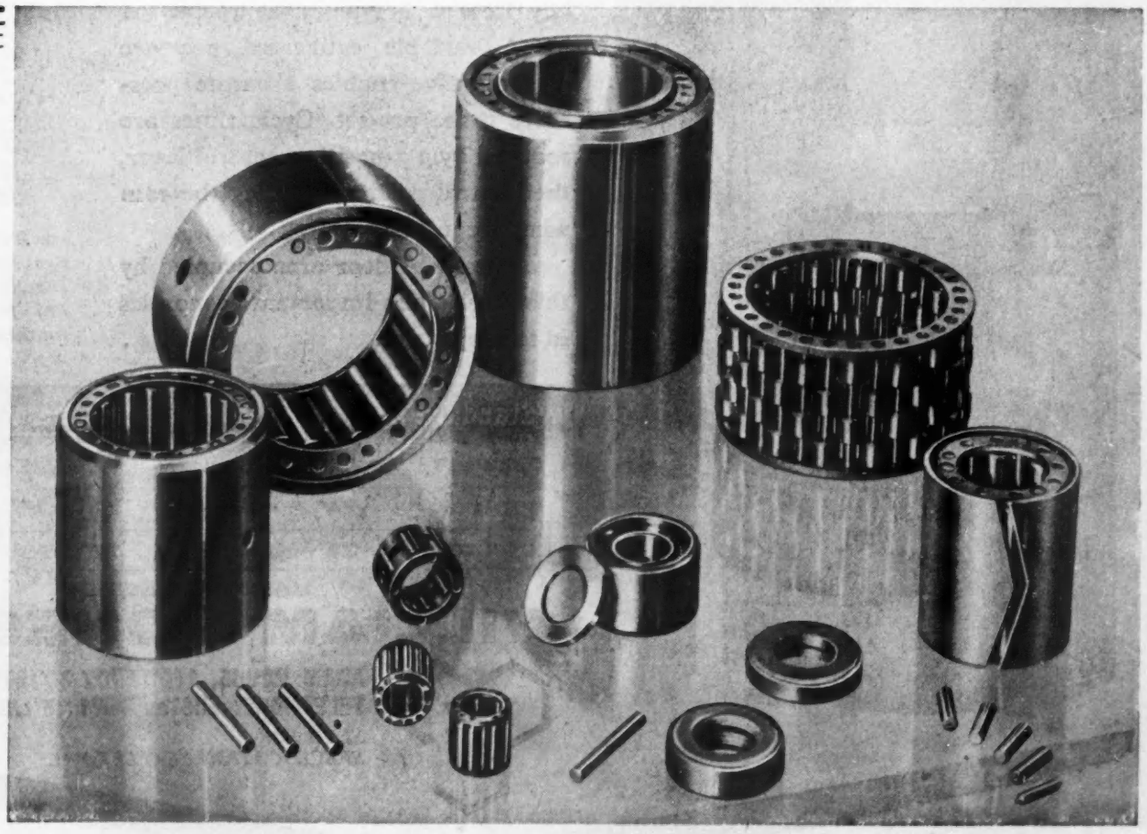

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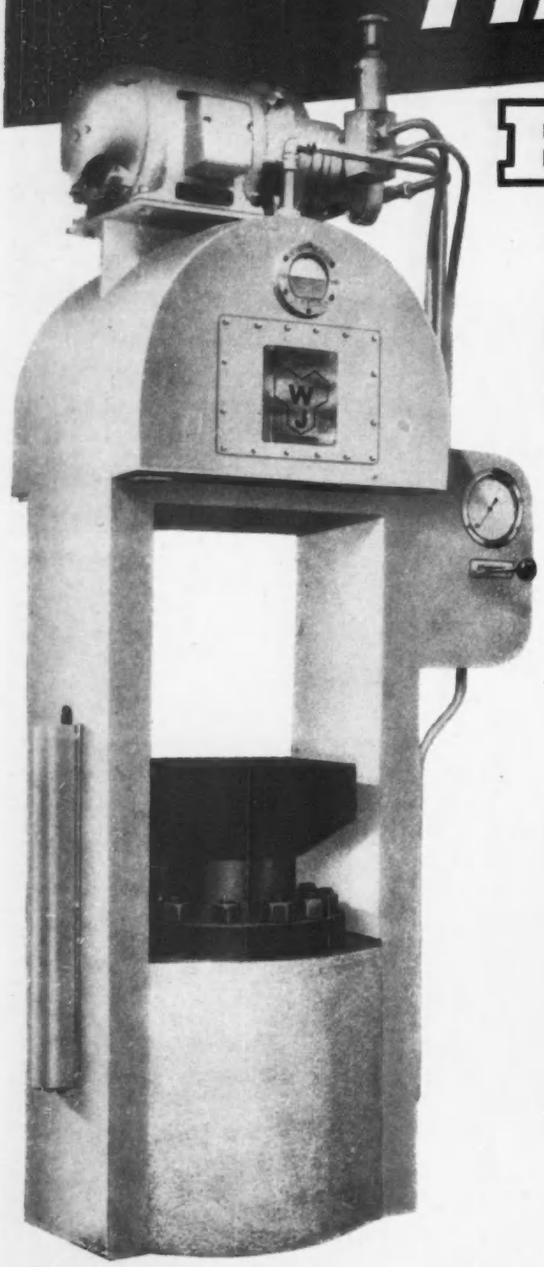
A 500 TON PRESS FOR LESS THAN £1750



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ARCH PRESSES

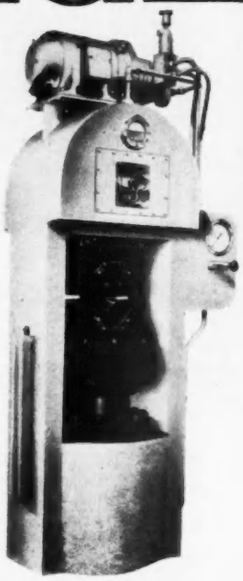
PATENT APPLIED FOR

COMPACT-ROBUST-RELIABLE SIMPLE TO CONTROL.....

Here is the *Prestige* Arch Press —a cold flow forging press that feature for feature is better and cheaper than any press of its type in the world.

A variable calibrated pressure control valve enables accurate pressures to be pre-set. Cycle times are reduced by a 3-position control lever, the neutral position holding the ram where required.

The small floor area occupied by this press offers important economies in factory space.



** A number of these Prestige Arch Presses are being supplied to British Ropes Ltd. for the SUPERLOOP mechanical splicing of wire rope.*

Standard Arch Presses in the PRESTIGE Range				
CAPACITY	DAYLIGHT	STROKE	TABLE SIZE	FLOOR AREA
500 TON	24"	6"	19" x 14"	32" x 24"
1,000 TON	24"	12"	36" x 36"	54" x 36"

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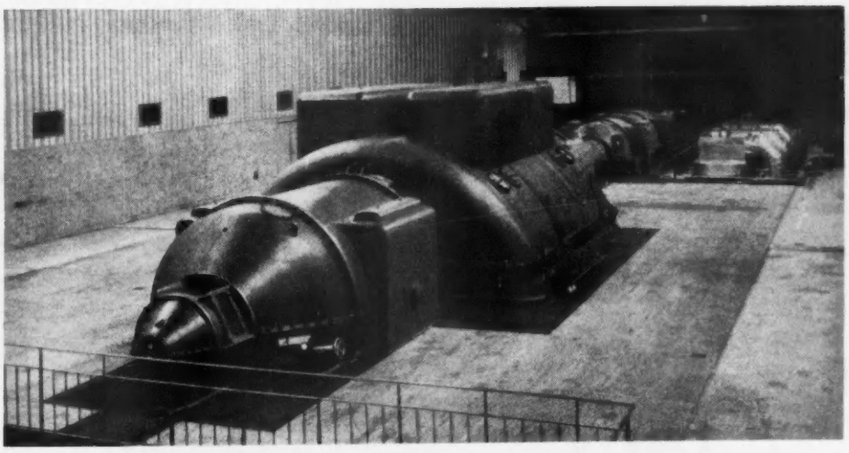
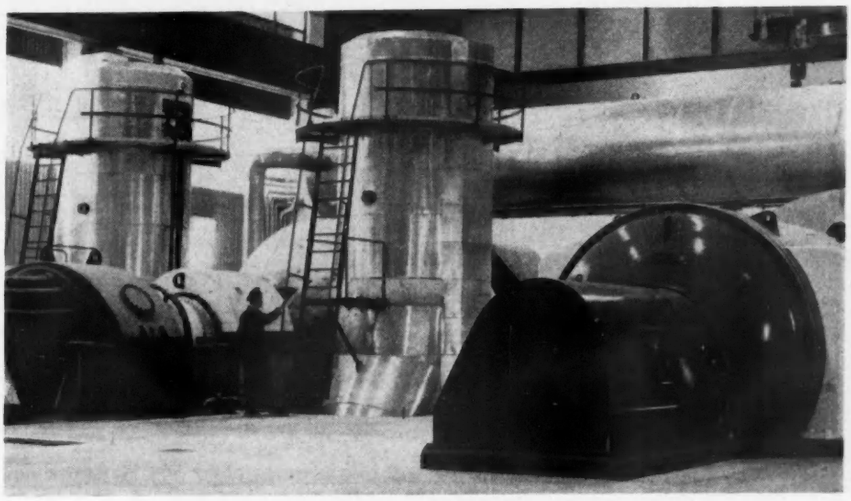


150,000 kW double rotation turbine, one of two in the Stenungsund plant of the Swedish State Power Board.



World's largest gas turbine, for 40,000 kW, in the Västervik plant of the Swedish State Power Board.

Largest in the world

The largest gas turbine in the world and the largest double rotation turbine are only two steps in the recent technical progress at de Laval Ljungstrom. Steam turbines for 300,000 kW (at 3,000—3,600 rpm) are already on the drawing board.

New designs, as the Durax and Quad, have eliminated earlier size limitations. As well, the double rotation system offers considerably lower transport weights than conventional designs. Further, appreciably higher efficiency figures have now been attained.

The recently amalgamated de Laval Ljungstrom companies now offer in 49 countries a complete programme of axial and radial turbines for land and marine applications, together with refrigerating equipment, high-precision gearing and pumps.

DE LAVAL LJUNGSTROM TURBINE CO.
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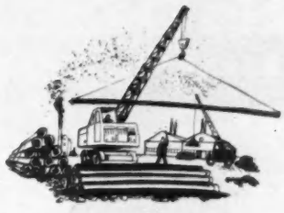

Our range of industrial engines are a practical proposition for many types of industrial equipment . . . **compressors, cranes, pumps, contracting equipment, earth borers, generators, railcars, welding plant, works trucks, tractors and conversions.** Simple design, modern flow-line production methods and common interchangeable parts contribute to the low cost of these high efficiency engines. And remember, every engine is fully backed by a World-wide Parts and Service Organisation. Take your choice from a wide power range . . . Diesel 20 to 86 b.h.p. and Petrol 11 to 87 b.h.p. (12-hr. rating).

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and the equipment they power, send the coupon to your nearest Ford Dealer or direct to

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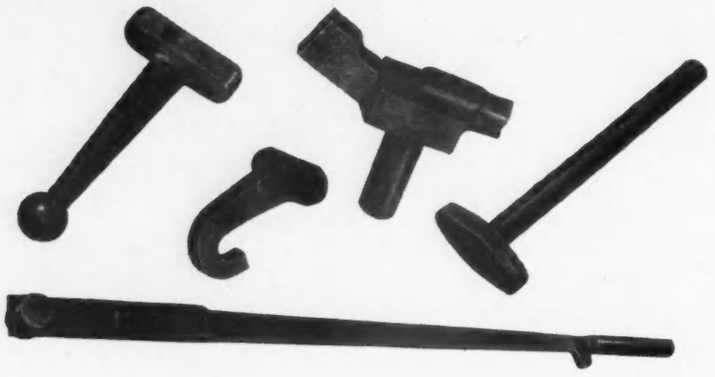
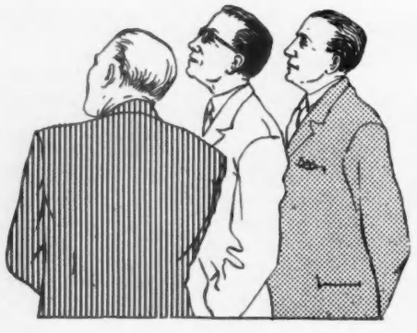
The illustrations show just a few examples of Cull craftsmanship.

All are completely hand forged. We supply hand and smithed forgings to any steel specification in the "as forged," normalised, annealed or oil hardened and tempered condition.





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Phone : MIDland 6048-9 Grams : CULANSONS, B'HAM

Works also at:

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if its different then send it to Culls"

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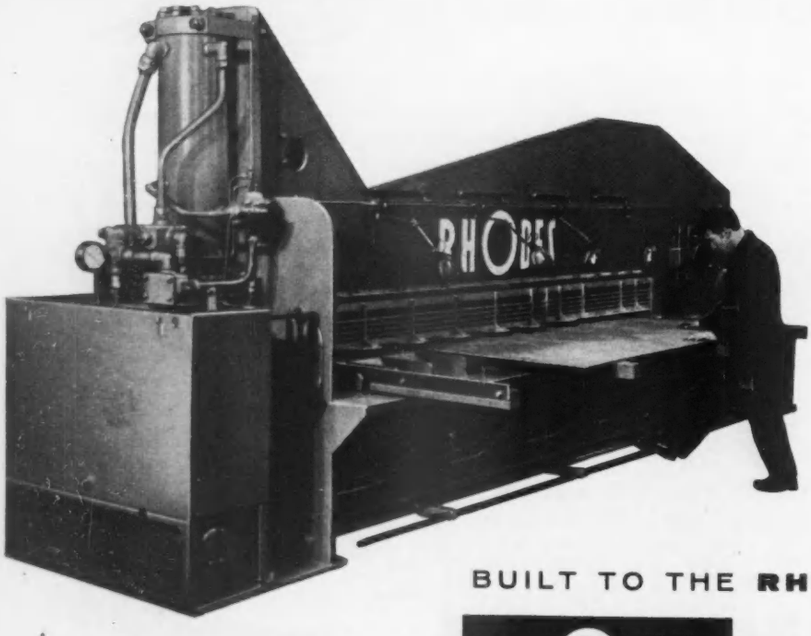
RHODES

HYDRAVERSAL SHEARS...

this isn't a 'gimmick'

it's a Shear necessity



...Does work of 5 machines. Costs less than 1.

It seems to have become a habit to describe any new machine as "Revolutionary" —the word has lost its meaning— and most of these so-called revolutionary machines are the same old designs with a gimmick tagged on to them. This puts us in a quandary. For how else should we describe the Hydraversal Shears? It does the work of 5 machines, costs less than one. You can get rid of your plate shears, cropping shears, trimming shears, billet shears, slab shears — the Hydraversal will do all their jobs better than they did it themselves. Trim a sheet or crop a billet—without adjustment. You can't break it. The secret is the patented "reverse-scissor" action. Revolutionary? Just a gimmick? Or, as we believe, a matter of intelligent simplification? Plus know-how—136 years of it.

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JOSEPH RHODES AND SONS LIMITED

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Not merely satisfied...

delighted!

with SMITH machines and SMITH service

We hear it at first-hand from the man-on-the-job; we read it (unsolicited) in our mail. Users go out of their way to tell us how much they appreciate the ***extra*** service and ***extra*** performance of Smith Cranes and Excavators – and the ever-ready spares and prompt service which make the vital difference.

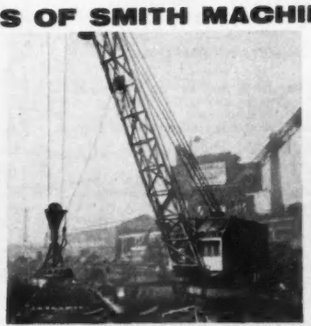
Our Service Engineer making his regular inspection check of a Smith Crawler Crane owned by GEE, WALKER & SLATER LTD. of Derby.

SMITH CRANES AND EXCAVATORS

SOME WELL-KNOWN USERS OF SMITH MACHINES

Welford Gravels Ltd. big producers of sand and gravel, employ many Smith excavators at their large quarries.

John Laing use many Smith Cranes and Excavators. The photo shows a Smith 21 dragline feeding a batching plant for the M1 Motorway



Cox and Danks Ltd., iron and steel scrap merchants, employ a Smith diesel loco crane with magnet equipment to handle scrap at their Manchester yards

Gibsons of Newcastle use a Smith truck crane (on hire to the Teeside Bridge & Engineering Works Ltd.) to position Dorman Long universal beams on a new bypass bridge

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There are reduced rates (i.e., not on a pro rata basis) for advertisements of ¼-page (12 column inches) and upwards, e.g., ¼-page £29 10s. ½-page £54. Full page £100.

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Run-On and Semi-Displayed Styles. Both these styles are available for single column width advertisements of any depth up to 12 inches.

Displayed and Illustrated Styles. The minimum size for a Displayed advertisement is 3 inches single column, for an Illustrated advertisement it is a ¼-page (12 column inches). Thereafter the sizes for both progress in steps 3 inches deep across 1, 2, 3 or 4 columns.

Use of Box Number. 2/- which includes forwarding of replies.

Copy Dates. Tuesday for publication on Friday of the same week. If proofs are wanted, copy is required on Thursday for publication on Friday of the following week.

***Advertisements for publication should be addressed to:*—Classified Advertisement Dept., "THE ENGINEER," 28 Essex Street, Strand, London, W.C.2**

Urgent advertisements may be telephoned to CENtral 6565.

PUBLIC APPOINTMENTS

KUMASI COLLEGE OF TECHNOLOGY, GHANA

THE SCHOOL OF ENGINEERING

ENGINEERING APPOINTMENTS

Under a rapidly developing expansion programme, the College invites applications for the following posts :

CIVIL ENGINEERING
SENIOR LECTURERS and LECTURERS in :
(a) Hydraulics.
(b) Engineering Structures.
(c) Soil Mechanics.
(d) Properties of Materials.
(e) Land Surveying.

MECHANICAL ENGINEERING
THE HEAD OF DEPARTMENT ;
SENIOR LECTURER IN STRENGTH OF MATERIALS ;
LECTURERS in :
(a) Strength of Materials.
(b) Theory of Machines.
(c) Engineering Drawing.

ELECTRICAL ENGINEERING
SENIOR LECTURERS or LECTURERS in :
(a) Generation and Distribution.
(b) Telecommunications.

A good Degree in Engineering is necessary for all posts, except the Lectureship in Surveying, for which the Professional Associate of the Royal Institution of Chartered Surveyors is acceptable. Post-graduate industrial and/or teaching experience is essential for all posts.

Contract appointments are normally for five years and may be renewed. Three months' notice of resignation of an appointment is required. Alternatively, an appointment may be accepted on pension at a lower salary.

The Contract Salary scales are :

Head of Department : £3430 by £112 10s. to £3767 10s. per annum.
Senior Lecturer : £2370 by £90 to £2910 per annum.
Lecturer, Grade A : £1987 10s. by £75 to £2437 10s. per annum.

A gratuity at the rate of £150 a year is payable at the end of a contract period. Children's allowances are paid up to a maximum of three.

The School is recognised by London University for the B.Sc. (Engineering) Degree, and the first group of students graduated in 1959. Courses are also conducted for the examinations of the Royal Institution of Chartered Surveyors.

The School of Engineering has very well-equipped laboratories and workshops, besides the usual staff rooms, lecture rooms and drawing-offices. Ample facilities for research are available.

The College is fully residential and members of staff are housed in pleasant, modern bungalows on the spacious campus ; climate and living conditions are good.

Application forms and an Information Brochure may be obtained from the Assistant Registrar, Reference E/E/2, Kumasi College of Technology, 29, Tavistock Square, London, W.C.1, who will also be glad to answer any questions about these appointments. The Principal of the College will be in London to interview candidates for these posts in April.
E9006

NORTHAMPTON COLLEGE OF ADVANCED TECHNOLOGY, ST. JOHN STREET, LONDON, E.C.1

LECTURER AND SENIOR LECTURER

Applications are invited for appointments as LECTURER and SENIOR LECTURER in the Department of Civil and Mechanical Engineering, dating from September, 1960, or earlier, in regard to the following subjects : Mechanics of Machines, Applied Thermodynamics, Strength and Properties of Materials, Mechanics of Fluids.

Applicants should be qualified to teach in courses for the Engineering Degree and Diploma in Technology and for Senior Lectureships should be able to make some contribution at post-graduate level in teaching or taking charge of research projects. Facilities are available for research by members of staff. These appointments are additional to the present staff and arise from the rapid growth in the work of the College.

Salary scales : Lecturer, £1370, rising to £1550 ; Senior Lecturer, £1550, rising to £1750, plus in each case London Allowance of £38, rising to £51 at age 37.

Further particulars and forms of application are obtainable from the Secretary, to whom applications should be sent by 21st March, 1960. E9030

PUBLIC APPOINTMENTS

UNIVERSITY OF LEEDS

DEPARTMENT OF CIVIL ENGINEERING

TWO LECTURESHIPS

Applications are invited for TWO LECTURESHIPS in Civil Engineering, at salaries on the scale £900 by £50 to £1350 (efficiency bar) by £75 to £1650 a year. Candidates should have had some practical experience and preference will be given to those with a special interest in at least one of the following subjects : Hydraulics, Surveying, Heating and Ventilation, Steelwork Design. Applications (three copies) stating date of birth, qualifications and experience, together with the names of three referees, should reach the Registrar, The University, Leeds, 2 (from whom further particulars may be obtained) not later than 1st April, 1960. E8887

UNIVERSITY OF LONDON KING'S COLLEGE

LECTURER OR ASSISTANT LECTURER IN CIVIL ENGINEERING

Applications are invited for this post. Candidates should have a good Honours Degree, some experience of teaching and/or research and professional experience is also desirable. The salary for an Assistant Lecturer is on the scale £700 by £50 per annum to £850, and for a Lecturer £900 by £50 per annum to £1350, then by £75 per annum to £1650. The starting point will be according to qualifications and experience. A London allowance of £60, family allowances and F.S.S.U. benefits will also be payable.

Conditions of appointment and application forms may be obtained from the Registrar, King's College, London, Strand, W.C.2, completed forms must reach him by 16th March. E8905

UNIVERSITY OF NOTTINGHAM

RESEARCH FELLOWSHIP IN PRODUCTION ENGINEERING

ENGINEERS, PHYSICISTS or MATHEMATICIANS, with research or industrial experience, are invited to apply for the above FELLOWSHIP, value £750 per annum, plus membership of the Universities' Superannuation Scheme.

Conditions of appointment and application form to be returned by 19th March from the Registrar.
E9011

KEIGHLEY AND DISTRICT VICTORIA HOSPITAL, KEIGHLEY, YORKSHIRE

(GENERAL—139 BEDS)

ASSISTANT ENGINEER

Must have completed an apprenticeship in mechanical engineering (as distinct from a wholly craft apprenticeship) or have otherwise acquired a sound, practical training in mechanical engineering.

Salary scale : £545 to £670, which is at present under review for upward adjustment.

Applications, giving full details of age, experience, &c., and names and addresses of three referees, to be forwarded to the Group Secretary, H.M.C.17, St. John's Hospital, Fell Lane, Keighley, as soon as possible. E8992

CITY OF COVENTRY WATER UNDERTAKING

ENGINEERING ASSISTANTS—3

Applications are invited from suitably qualified ENGINEERS for : (a) 2 posts requiring Civil Engineering experience, and (b) a post in the Supply Works Group requiring mechanical and electrical engineering experience. Salary according to qualifications and experience, within Special (£785–£1070)/A.P.T. IV (£1065–£1220).

Housing accommodation may be provided and a removal expenses loan may be considered.

Closing date, 11th March, 1960.

Further particulars and conditions from Water Engineer and Manager, Waveley Road, Coventry. E9021

PUBLIC APPOINTMENTS

CENTRAL ELECTRICITY GENERATING BOARD

NORTH EASTERN AND YORKSHIRE REGION

STEAM TESTING DEPARTMENT

SENIOR ASSISTANT ENGINEER

Applications are invited for the appointment of SENIOR ASSISTANT ENGINEER in the Steam Testing Department of the North Eastern Division.

The successful candidate will be based at Dunston-on-Tyne and will assist the Steam Testing Engineer with the planning and co-ordination of performance tests and investigations on modern steam plant, with the critical assessment of data and the preparation of reports.

Applicants should possess a University Degree or equivalent qualification, and should preferably have some experience of plant testing, or relevant experience of plant operation or project development.

The salary for the appointment (which is superannuable) will be in accordance with the N.J.B. Agreement, Schedule B, Grade 3 (£1365–£1595) and will commence at a point commensurate with qualifications and experience.

Forms of application may be obtained from Assistant Regional Secretary (Personnel), Central Electricity Generating Board, North Eastern and Yorkshire Region, 1, Whitehall Road, Leeds, 1, to whom they should be returned, to arrive not later than 31st March, 1960. E8986

REPUBLIC OF THE SUDAN

DEPUTY CHIEF MECHANICAL ENGINEER

Applications are invited from those suitably qualified to fill a vacancy of DEPUTY CHIEF MECHANICAL ENGINEER in the Sudan Gezira Board—Sudan. Candidates should be professionally qualified engineers with comprehensive experience in modern engineering workshop practice, stationary diesel engine maintenance and vehicle maintenance. Electrical experience with transformers and switchgear motors. Drawing office and design experience is desirable together with experience of installation work using direct and contracted labour.

Age not under 30 years.

Appointment will be on contract, for a period of three years. Salary range £S.1400 to £S.1800. Point of entry will be determined according to age, qualifications and experience. A gratuity representing one-fifth of total basic salary will be paid on satisfactory completion of contract.

A cost of living allowance is payable and an initial outfit grant of £S.60 on appointment. Housing will be provided free by the Board and hard furnishing at nominal rent. Free passage given on appointment and annual leave. There is no income tax payable in the Sudan at present.

Applications should be made in writing, quoting full particulars together with copies of recent testimonials, to The Sudan Embassy, Appointments Section, Cleveland Row, St. James's, London, S.W.1. Quoting reference 4/2421. Closing date 31st March, 1960. E8978

HER MAJESTY'S OVERSEAS CIVIL SERVICE

GOVERNMENT OF HONG KONG

MECHANICAL ENGINEER, KOWLOON-CANTON RAILWAY

(To take up appointment in May, 1960.)

Responsible to the General Manager of the Railway for the efficient organisation and running of the Railway Workshops, including maintenance and major overhauls of diesel-electric locomotives, carriages and wagons, and ancillary heavy equipment. Pensionable appointment or on secondment if on the staff of British Railways. Salary range : £1500–£2865. Free passages. Rented quarters.

Candidates, up to 35 years, must be A.M.I.Mech.E. with at least six years' relevant experience in a senior post.

Write to Director of Recruitment, Colonial Office, London, S.W.1, giving full names, age, qualifications and experience, quoting BCD 110/51/02/D4. E8931

PUBLIC APPOINTMENTS

ILFORD AND BARKING GROUP HOSPITAL MANAGEMENT COMMITTEE

GROUP WORKS DEPARTMENT

ASSISTANT ENGINEER

Group Works Department, Ilford Maternity Hospital, Eastern Avenue, Ilford, Essex (adjacent to Newbury Park Station—Central London Line).

ASSISTANT ENGINEER required, to assist Superintendent Engineer in the supervision of the Engineering and Building Services in this Group.

Applicants must have a first-class knowledge of Mechanical Engineering and Building Services, also drawing-board experience. Knowledge of electrical installations would be an advantage.

Preference will be given to candidates who are studying engineering technology.

The post is subject to the terms and conditions of the appropriate Whitley Council. Salary : £545 (1 by £20, 3 by £25, 1 by £30) to £670, plus London Weighting. (Salary under review.)

Apply in writing, stating age, qualifications, details of experience, together with names and addresses of three referees, to the Group Secretary, King George Hospital, Ilford, Essex, within 14 days of the appearance of this advertisement. E9024

CENTRAL ELECTRICITY GENERATING BOARD

ASSISTANT ENGINEERS

Applications are invited for appointments in the Station Planning Section of the Planning Department at Headquarters, London, S.E.1.

The Section is concerned with the planning of new generating capacity in England and Wales. It is responsible for the investigation and selection of sites for conventional power stations ; for the nuclear power stations required to implement the nuclear power programme and for the negotiations for statutory and other consents for both classes of station.

Candidates should possess an Honours Degree or the requisite qualifications for corporate membership of the Institution of Mechanical, Civil or Electrical Engineers. A sound engineering or scientific background is essential and an aptitude for forward thinking is desirable. It will also be an advantage to have had experience of economic studies or of one or more of the problems arising in the siting of power stations, e.g. fuel transport and reception ; the thermal and hydraulic aspects of the use of large volumes of river or sea water for cooling purposes ; ash disposal ; questions of town and country planning.

Salaries within the range £1140–£1350 p.a.

Applications, stating age, qualifications, experience, present position and salary, to the Personnel Officer, 24-30, Holborn, London, E.C.1, by 7th March. Envelopes should be marked "Confidential Ref. ENR/65." E8933 A

CITY OF SHEFFIELD

SEWAGE DISPOSAL DEPARTMENT

GENERAL MANAGER

Applications are invited for the appointment of General Manager of the Sewage Disposal Department, at a salary of £2325 per annum, rising by four annual increments of £60 and a final increment of £45 to £2610 per annum. (J.N.C. Scale 1.)

Applicants should have had considerable experience in the administration of a large Sewage Disposal Department, and should be suitably qualified engineers or chemists.

The person appointed will succeed Mr. J. H. Edmondson, M.I.Mech.E., M.I.Chem.E., and will be required to devote his whole time to the duties of his office.

The appointment is subject to a medical examination, superannuation, three months' notice on either side, and the conditions of service of the J.N.C. for Chief Officers of Local Authorities.

Applications, which must be made on the official form, obtainable from me upon request, must reach me on or before 18th March, 1960.

Canvassing in any form will disqualify.

JOHN HEYS,
Town Hall, Town Clerk.
Sheffield, 1. E9026

PUBLIC APPOINTMENTS

GUILDFORD, GODALMING AND DISTRICT WATER BOARD

(AMENDED ADVERTISEMENT)

APPOINTMENT OF ENGINEERING STAFF

Applications are invited for the following appointments :

(a) ENGINEERING ASSISTANT (Capital Works). (Non-established Post.) A.P.T. IV (£1065–£1220 per annum).

(b) SENIOR ENGINEERING ASSISTANT (Established Post). Special Grade (£785–£1070 per annum).

Commencing salaries in accordance with qualifications and experience.

Candidates for post (a) should have had good experience in the design and construction of Capital Works, preferably on water supply schemes. A practical knowledge of water retaining structures, including the preparation of drawings and contract details, would be an advantage.

Candidates should be Associate Members of the Institution of Civil Engineers.

Candidates for post (b) should have had good experience in the general work of a Water Undertaking and have passed Parts I and II of the Associate Membership Examination of the Institution of Civil Engineers.

Both appointments will be subject to the National Scheme of Conditions of Service, the Local Government Superannuation Acts, and to the passing of a medical examination.

Applications, stating age, training, present and previous appointments and experience, and names and addresses of two referees, must be received by the Chief Engineer, " Branksome," Filmer Grove, Nightingale Road, Godalming, not later than Monday, the 14th March, 1960.

Housing accommodation will be made available if required.

Car allowance payable on " Casual User " basis.

H. C. WELLER, LL.B.,
Clerk to the Board.

Municipal Offices,
High Street,
Guildford. E9029

SHEFFIELD CORPORATION WATERWORKS

YORKSHIRE DERWENT SCHEME

TWO CHIEF ASSISTANT ENGINEERS

Applications are invited for the following appointments on the staff of the Waterworks General Manager and Engineer (A. B. Baldwin, M.Eng.) :

TWO CHIEF ASSISTANT ENGINEERS i/c. Sub-sections, J.N.C. Scale " A " salary : £1215 to £1445.

Successful applicants will be engaged upon the design and construction of the works of the Yorkshire Derwent Scheme, comprising a river intake and treatment plant, a 40-mile aqueduct, service reservoirs, pumping stations and plant.

Applicants must be Chartered Engineers experienced in the design and construction of major works, and previous employment on similar water supply schemes would be an advantage.

Appointments are superannuable and subject to medical examination and to the National Conditions of Service as applied by the City Council.

Applications, stating age, qualifications, present and past appointments (with dates and salaries), details of relevant experience and schemes engaged upon, and quoting the names and addresses of two referees, should reach the undersigned not later than the 12th March, 1960.

JOHN HEYS,
Town Clerk.

Town Hall,
Sheffield, 1. E9013

FOUNTAIN HOSPITAL

SENIOR ENGINEER

SENIOR ENGINEER required at the Fountain Hospital, Tooting Grove, London, S.W.17. Applicants should have completed an apprenticeship in mechanical engineering or have otherwise acquired a practical training in mechanical engineering as distinct from a purely craft training. They must also hold a First Class Certificate of Competency in Marine Engineering (or equivalent Naval Certificate) or an approved equivalent qualification which includes Heat and Heat Engines and an endorsement in the principles of Electricity. The person appointed will be required to live in accommodation at the hospital at an appropriate rental. Salary scale for suitably qualified applicant £680 per annum rising to £815 per annum, plus London weighting of £30 per annum at age 26. Applications giving full details of age, qualifications and experience, and names and addresses of two referees (employers) to be sent to the Secretary immediately. E8973

CIVIL SERVICE COMMISSION

SENIOR SCIENTIFIC OFFICERS (A) SCIENTIFIC OFFICERS (B)

SENIOR SCIENTIFIC OFFICERS (a) : SCIENTIFIC OFFICERS (b).

Pensionable posts for men or women in all major scientific fields, including physics, chemistry, biology, meteorology and mathematics. Age limits : (a) at least 26 and under 32 ; (b) at least 21 and under 29. Extension for regular Forces Service and Overseas Civil Service.

Qualifications : normally First or Second Class Honours Degree in Science, Mathematics or Engineering, or equivalent attainment ; additionally for (a) at least 3 years' relevant (e.g. post-graduate) experience. London salaries (men) : (a) £1233–£1460 ; (b) £655–£1150 ; provision for starting pay above minimum. Promotion prospects.

Write, Civil Service Commission, 17, North Audley Street, London, W.1, for application form, quoting : (a) S/53/60 ; (b) S/52/60. E9003

PUBLIC APPOINTMENTS

UNIVERSITY OF ALBERTA

Invites applications for Academic Appointments in the

FACULTY OF ENGINEERING

CHEMICAL ENGINEERING

- ASSISTANT PROFESSOR—Ph.D. preferably with background in Fluid Mechanics and Reaction Kinetics.

CIVIL ENGINEERING

- TWO ASSISTANT PROFESSORS—Ph.D. or M.Sc. with background in Structural Analysis and Design.
- ASSISTANT PROFESSOR—Ph.D. or M.Sc. with background in Strength of Materials and Structural Analysis.
- ASSISTANT PROFESSOR—Ph.D. or M.Sc. with background in Sanitary Engineering.

ELECTRICAL ENGINEERING

- PROFESSOR—Ph.D. with substantial experience in TEACHING and/or RESEARCH and with special background in Microwaves or Transistor Circuitry. Appointment to be made June 1, 1960
- ASSISTANT PROFESSOR—Ph.D. or M.Sc. with background in electronics preferably in Transistor Circuitry or Microwaves.

MECHANICAL ENGINEERING

- ASSISTANT PROFESSOR—Ph.D. or M.Sc. with special background in Thermodynamics.
- ASSISTANT PROFESSOR—Ph.D. or M.Sc. with special background in Fluid Mechanics and Heat Transfer.

PETROLEUM ENGINEERING

- ASSISTANT PROFESSOR—Ph.D. or M.Sc. preferably with background and interest in Drilling Methods and Reservoir Engineering.

Applications will be considered only from persons having first class academic records and with proven ability, or strong recommendations as to their potential, in TEACHING and RESEARCH. Some industrial experience is desirable but not essential. Appointees will be expected to participate in both undergraduate and graduate teaching and to initiate and direct graduate research programs. Considerable freedom to engage in consulting work may be expected. Promotion prospects for the right people are excellent. The salary schedule for the 1960–61 academic year is : Assistant Professor—$6,000 to $8,200 ; Associate Professor—$8,500 to $10,700 ; Professor—$11,000 minimum. Except where otherwise noted appointments will commence September 1, 1960.

Fully documented applications including recent photograph ; personal statistics ; transcripts of all academic records ; résumé of teaching, research, and industrial experience; list and reprints of publications ; and list of references may be sent to—

DEAN, FACULTY OF ENGINEERING
UNIVERSITY OF ALBERTA, EDMONTON, ALBERTA

E8983 A

PUBLIC APPOINTMENTS

CENTRAL ELECTRICITY GENERATING BOARD

EASTERN DIVISION

Applications are invited for the following appointment :

ASSISTANT ENGINEER—BRADWELL (ESSEX) NUCLEAR GENERATING STATION (MAINTENANCE)

Salary : N.J.B., Class M, Grade 12, £965 by £20 to £1025 per annum.

Applicants should have served an apprenticeship in general engineering and the possession of an Ordinary National Certificate would be an advantage.

The successful applicant will be engaged on general duties within the Maintenance Department, including technical records. Considerable experience of all types of Drawing Office work is essential. Some experience in drawing simple isometric sketches and cut-away perspectives would be an advantage.

Applications, quoting Staff Vacancy No. 1249, stating age, qualifications, experience and present position, should be sent to the Controller, Central Electricity Generating Board, Eastern Division, West Farm Place, Chalk Lane, Cockfosters, Barnet, Herts., to arrive not later than 5th March, 1960. E9034

MINISTRY OF AVIATION

WOOLWICH

TECHNICIAN

Ministry of Aviation requires TECHNICIAN at Woolwich, to assist with assessment of trials of components for all types of guided weapons. This includes all phases of testing, covering preparation of design sketches for test rigs, compiling working instructions, reports on results, setting up equipment and instrumentation, carrying out and supervising tests.

Qualifications : Recognised engineering apprenticeship. Some electrical knowledge with use of instrumentation essential. O.N.C., C. and G. Finals, or equivalent.

Salary : £900 (age 30) to £1065 per annum.

Application forms from Manager (P.E.802), Ministry of Labour, Professional and Executive Register, Atlantic House, Farringdon Street, London, E.C.4. E9036

RIVER DOVE WATER BOARD

ASSISTANT CIVIL ENGINEER

ASSISTANT CIVIL ENGINEER required for new capital works. Part or fully-qualified men may apply. Salary will depend on age and experience, with a maximum of £1070 for qualified Engineers with 5 years' training and experience at age 28.

National Conditions of Service. Post superannuable and subject to medical examination.

Applications to Engineer and Chief Executive, River Dove Water Board, Bowling Green Street, Leicester, by 10th March, 1960. E9028

TENDERS

GREAT OUSE RIVER BOARD

EXTENSION OF WESTERN TRAINING WALL

CALL FOR TENDERS

The Great Ouse River Board invite TENDERS for the EXTENSION OF THE WESTERN TRAINING WALL of the River Great Ouse, near King's Lynn, Norfolk.

The work comprises the CONSTRUCTION of about 2000 feet of an extension to the Western Training Wall at the entrance of the Marsh Cut from the Wash at King's Lynn, using fascine mattresses and pitching.

A copy of the drawings and other contract documents may be obtained on or after 29th February, 1960, from the Consulting Engineers, Sir M. MacDonald and Partners, 72, Victoria Street, London, S.W.1, on payment of a deposit of Five Guineas, which is returnable to bona fide Tenderers.

Application for the documents must be in writing.

Only Tenders from firms who have had experience in this class of work and who have, or can obtain, the necessary plant, will be considered.

Tenders must be received not later than mid-day on 8th April, 1960.

(Signed) K. M. RODDIS,
Clerk of the Great
Ouse River Board.

" Elmhurst,"
Brooklands Avenue,
Cambridge. E8988

MID-NORTHAMPTONSHIRE WATER BOARD

CONTRACT NO. 443

The Board invite TENDERS for the CONSTRUCTION of a REINFORCED CONCRETE WATER TOWER of 50,000 gallons capacity with associated pipework, situated at Rothwell, in the County of Northamptonshire.

Tender documents may be obtained from me on payment of a deposit for £2 2s., such deposit being returnable. Completed Tenders should be received by me not later than 25th March, 1960.

LEONARD H. BROWN,
Engineer and Manager.

Cliftonville,
Northampton. E9017

Classified Advts. continued on page 118

TENDERS

GOVERNMENT OF CEYLON

The Chairman, Tender Board, Ministry of Works, Transworks House, Colombo, Ceylon, will receive TENDERS up to 9.30 a.m. on Wednesday, 15th June, 1960, for the TOWNS SOUTH OF COLOMBO WATER SUPPLY SCHEME, STAGE II—SECTION "PIPE LINES, PUMPS, DIESEL GENERATOR SETS AND CONNECTED EQUIPMENT." Tenders will be opened at 2.30 p.m. on the same day and at the same place in the presence of the Tenderer or his representatives.

2. Tenders should be made in triplicate in accordance with the condition of Tender, specification, &c., which may be obtained at the Office of the Chief Engineer, Construction and Maintenance (Water-Works), Public Works Department, Ratmalana, Ceylon, or other issuing officers noted hereunder up to noon on Monday, 21st March, 1960, on payment of a Tender deposit of Rs.1000/– where the Tender is issued in Ceylon, and on payment of a Tender deposit of £100 and a Tender fee of £10 where the Tender is issued elsewhere. Sealed Tenders may be sent either under registered cover addressed to the Chairman, Tender Board, Ministry of Works, Transworks House, Colombo, Ceylon, or handed personally to him. The sealed Tenders should state on the cover particulars of service and the name and address of the Tenderer.

3. When appyling for Tender forms, Tenderers should produce evidence that they have done similar work elsewhere and that they have employees on their staff fully qualified to undertake the proposed work. They should also produce evidence that they have Local Agents in Ceylon. They should further be prepared to furnish names and addresses of their proposed sureties.

4. Tenderers should keep their Tenders open for a period of 60 days from the closing date of this Tender to enable the consideration of the Tenders received.

5. Tender forms and connected documents will be issued by :—

(a) In Ceylon by the Chief Engineer, Construction and Maintenance (Water-Works) Public Works Department, Ratmalana, Ceylon.

(b) In all overseas countries, by the Consulting Engineers, Messrs. Eau et Assainissement, 6, rue Piccini, Paris 16, France.

Prospective overseas Tenderers, if they so wish, may also obtain the Tender forms and connected documents through the diplomatic representatives of the Ceylon Government mentioned below, who will also keep a set each of specimen Tender forms and documents for examination only.

1. Office of H.E. the High Commissioner for Ceylon in the United Kingdom.
2. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in the U.S.A.
3. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in Germany.
4. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in Italy.
5. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in France.
6. Office of the High Commissioner for Ceylon in Australia and New Zealand.
7. Office of the High Commissioner for Ceylon in Canada.
8. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in China.
9. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in Japan.
10. Office of H.E. the Ambassador Extraordinary and Minister Plenipotentiary for Ceylon in U.S.S.R.

6. The Tender deposit should be made at the P.W.D. Head Office, Colombo, Ceylon, by local Tenderers. Overseas Tenderers should pay the Tender deposit and Tender fee to Messrs. Eau et Assainissement, 6 rue Piccini, Paris 16, France, or to any one of the Diplomatic Representatives of the Ceylon Government in the countries mentioned above.

C. RASIAH,
for Director of Public Works.

Public Works Office,
Colombo.
19th February, 1960. E8980

INDIA SUPPLY MISSION

The Office of the India Supply Mission, 2536, Massachusetts Avenue, N.W., Washington 8, D.C. United States of America, invites TENDERS for the following :

TENDER ENQUIRY No. S.E.146

(a) For the SUPPLY of TWO SETS 5000 g.p.m., 80ft head ELECTRICAL PUMPS with Accessories required by Neyveli Lignite Corp. (Private), Ltd., Madras, India.

TENDER ENQUIRY No. S.E.147

(b) For the SUPPLY of EQUIPMENT for MATERIAL TESTING LABORATORY, consisting of (i) Industrial X-ray Apparatus ; (ii) Ultrasonic Flaw Detector ; (iii) Brinell's Hardness Testing Machine ; (iv) Cement Testing Machine ; (v) Spring Testing Machine ; (vi) Torsion Testing Machine ; (vii) Fatigue Testing Machine. Required by Neyveli Lignite Corp. (Private), Ltd., Madras, India.

TENDER ENQUIRY No. S.E.149

(c) For the SUPPLY of ONE TRENCHING MACHINE for 2ft. by 2ft. Trenches, on Lignite and clay soil. Diesel-driven, tyred or tracked. Required by Neyveli Lignite Corp. (Private), Ltd., Madras, India.

Specifications, &c., relative to the above specification, can be obtained from the Co-ordination Branch, India Store Department, Bromyard Avenue, Acton, W.3, at a cost of 14 shillings and 3 pence per Tender Enquiry, and is not refundable.

Tenders are to be returned direct to India Supply Mission, 2536, Massachusetts Avenue, N.W., Washington 8, D.C., United States of America, so as to reach them by (a) 7th April, 1960 ; (b) 7th April, 1960 ; (c) 12th April, 1960.

Specimen copy of the above enquiry can be seen at Engineering Branch, India Store Department, Bromyard Avenue, Acton, W.3, under the following reference (a) S.4068/59/NSC/ENG.2 ; (b) S.4069/59/NSC/ENG.2 ; (c) S.4111/59/NSC/ENG.2. E9027

TENDERS

N.A.T.O. UNCLASSIFIED

N.A.T.O. COMMON INFRASTRUCTURE

SLICES VII AND VIII

NAVAL BASE INSTALLATIONS

Final Notice is hereby given that International Competitive Bids will be invited on or about 27th April, 1960, for the

SUPPLY and INSTALLATION of the COMPLETE ELECTRICAL INSTALLATION for a P.O.L. STORAGE DEPOT to be constructed in the Loch Striven area of Scotland.

The system will be 415 volts, 3-phase, 4-wire, 50 cycles.

2. The approximate total value of the works is £55,000 and the contract will comprise :

Switchgear and Control Equipment.
Cables for Distribution, Motors and Controls
Oil pipeline Heating System.
Street and Area Lighting.
Power and Lighting in Buildings.
Earthing and Bonding.

3. The work will be carried out as one contract which will be undertaken as a sub-contract within the framework of the Main Contract for the construction of the Depot. Bids for the Main Contract have been invited.

4. It should be noted that the importation of labour from sources outside the United Kingdom may be subject to restriction and that permission could, in any case, only be given on an undertaking that the Contractor would pay rates of wages and observe hours and conditions of labour not less favourable than those established for U.K. labour for the trade or industry in the same area.

5. The closing date for the receipt of bids will be 22nd June, 1960.

6. Firms wishing to bid must formally notify their desire by application to the address below by 23rd March, 1960.

7. Within one week after the closing date for the receipt of applications to bid, firms wishing to be invited must forward the following information :

(i) Statement of financial resources and evidence of financial stability.

(ii) Details of recent major contracts completed for work of a comparable nature, including an indication of the value of each.

8. Enquiries regarding bidding should be addressed to :

Director General, Navy Works,
Admiralty,
Chamberlain Way,
Pinner,
Middlesex,
England.

quoting reference C.E.-in-C./Infra/9 (Sub-Contract Electrical Installation). E9039

COUNTY COUNCIL OF ESSEX

GREAT BENTLEY COUNTY PRIMARY SCHOOL

IMPROVEMENTS TO HEATING INSTALLATION

Contractors wishing to submit a firm price TENDER for the above should forward names, from which a panel will be chosen and provided with Tender documents.

The work, which must be carried out during the school summer holiday period, 1960, consists of improvements to the Heating Installation and the provision of Oil-fired Equipment, estimated cost £2300.

Applications to reach the undersigned not later than 5th March, 1960.

H. CONOLLY, C.B.E., F.R.I.B.A.,
County Architect.
County Hall,
Chelmsford. E9022

EDUCATIONAL

UNIVERSITY OF MANCHESTER

POST-GRADUATE COURSE IN NUCLEAR ENGINEERING

This COURSE, which is of one year's duration, is intended for Graduate Engineers, Physicists or Metallurgists who wish to specialise in the field of Nuclear Engineering. Students attend a course of lectures on the fundamentals of the subject, supplemented by selected topics at a more advanced level, and also undertake an experimental project. The Diploma for Advanced Studies in Science is awarded to candidates who successfully complete the course. Application has been made to the Department of Scientific and Industrial Research for acceptance of the Post-graduate Course in Nuclear Engineering as suitable for the tenure of its Advanced Course Studentships.

All applications and enquiries should be addressed to Professor W. B. Hall, Nuclear Engineering Laboratories, The University, Manchester, 13. E9012 E

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

Bursaries available for postgraduate courses in Aeronautics, Chemical, Civil, Electrical and Mechanical Engineering for Session 1960–61. Value £500–£700. Applicants should be United Kingdom residents, who must have spent at least one year away from University since graduation preferably in industry. Further information from Registrar, Imperial College, London, S.W.7. Closing date May 18th, 1960. E8970 E

A.M.I.MECH.E., B.Sc., City and Guilds, etc. Guarantee Postal Courses for all Exams. and Technical Divisions from Elementary to Degree standard including Automation Techniques. Approximately 95 per cent. successes. 148-page prospectus free, on request.—B.I.E.T. (Dept. 22), 29, Wright's Lane, London, W.8. E114 E

EDUCATIONAL

ADMIRALTY

ROYAL CORPS OF NAVAL CONSTRUCTORS

SCHOOLS ENTRY

A competition for entry into the Royal Corps of Naval Constructors will be held in July, 1960.

2. Accepted candidates will be established as probationers in the Royal Corps of Naval Constructors and will undergo a two-year course of training at the R.N. Engineering College, Manadon, and in H.M. Dockyard, Devonport, followed by a three-year course at the R.N. College, Greenwich.

3. Candidates must be aged between 17 years 6 months and 19 years 6 months, inclusive, at 1st September, 1960.

4. Candidates with the General Certificate of Education will be required to have passed at Advanced Level in at least Pure Mathematics, Applied Mathematics, and Physics taken on the same occasion, and at least Ordinary Level passes in English and a language other than English.

5. Candidates with the Scottish Leaving Certificate will be required to have Higher grade passes in Science (to include Physics), Mathematics, at least two additional mathematical subjects (one of which must be Dynamics), and at least lower grade passes in English and a language other than English. Passes to be gained at not more than two sittings of the Scottish Leaving Certificate examination.

6. Candidates with the Northern Ireland Grammar School Senior Certificate will be required to have passes at Advanced Level in Mathematics (General Course, Pure Mathematics, Applied Mathematics) and Physics—taken on the same occasion ; and at least Ordinary Level passes in English and a language other than English.

7. Applications will be considered from candidates who sit these examinations in 1960.

8. The work of the R.C.N.C. covers all aspects of design, construction and repair to H.M. Ships. Members undertake to serve wherever required at Admiralty headquarters, Outports in the United Kingdom and at Royal Dockyards at home and abroad.

9. The starting pay of a probationer at age 18 will be £545. A deduction of £75 is made when living in at the R.N. Engineering College, Manadon, or at the R.N. College, Greenwich. The successful probationer can expect an appointment as Assistant Constructor at age 23 or 24 with a starting salary of not less than £910 and £940 respectively. Promotion to Constructor normally takes place at about age 30 with a salary which may be expected to be not less than £1515, rising in nine years to not less than £2255. Promotion to higher ranks is by selection.

10. Full particulars may be obtained from the Secretary of the Admiralty, Civil Establishments Branch II(88), Empire Hotel, Bath, quoting reference number 6015, to whom final application must be submitted by 16th May, 1960. E8783 E

CITY AND COUNTY OF BRISTOL EDUCATION COMMITTEE

THE COLLEGE OF TECHNOLOGY, ASHLEY DOWN, BRISTOL, 7

SHORT COURSES OF LECTURES dealing with the following subjects will be held at the College.

1. HYDRAULIC SERVO SYSTEMS FOR ENGINEERS.
Weekly evening series. Commencing Thursday, 3rd March.
Enrolment fee : £2 2s. 0d.
2. INFRA RED.
For Physicists and Engineers. Saturday, 19th March.
Enrolment fee : £2 2s. 0d.
3. INFORMATION—THEORY AND NOISE.
Friday/Saturday, 8/9th April.
Enrolment fee : £2 2s. 0d.

Enrolment forms and particulars from the Organiser of Short Courses at the College. E9000 E

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY

BURSARIES IN CONCRETE TECHNOLOGY

Bursaries of £460–£760 according to experience are available for Session 1960–61. Candidates must hold a degree in engineering and have a good knowledge of the theory of structures. Full information from the Registrar, Imperial College, London, S.W.7. Closing date June 1st, 1960. E8971 E

SITUATIONS VACANT

APPLICANTS ARE ADVISED TO SEND COPIES NOT ORIGINALS OF THEIR TESTIMONIALS UNLESS OTHERWISE REQUESTED.

A QUALITY CONTROLLER is required for a Company manufacturing Household Appliances in Central Scotland. The successful applicant will be a trained Engineer with sound experience in modern principles and practical application of Quality Control. He will be familiar with British Standard Quality Control Specifications and Statistical approach to Sampling Inspection. The Quality Controller will report directly to top Management and will be covered by Company Life Insurance and a Contributory Superannuation Scheme.—Replies will be treated in strict confidence and should be addressed to BOX No. E2733, "The Engineer." A

ALL GRADES OF ENGINEERS AND DRAUGHTSMEN required immediately. High starting salary. Please phone AMB 8189. E2731 A

AMERICA.—Excellent positions and opportunities now available for skilled men. Wide range of trades required. Write, giving fullest particulars of experience and qualifications.—Belgravia Agency (Industrial), 35, Brompton Road, London, S.W.3. Telephone : Knightsbridge 4343 (20 lines). E2738 A

SITUATIONS VACANT

A.E.R.E., HARWELL PROFESSIONAL ENGINEERS

are required for

the REACTOR SERVICES GROUP to carry out technical calculations and assessments in the following fields :

HEAT, TRANSFER, FLUID FLOW
SHIELDING
STRESSING
SAFETY ANALYSIS OF IRRADIATION EXPERIMENTS.

The work involves co-operation with design engineers, scientists and contractors engaged on work for A.E.R.E.

Applicants should have corporate membership of a senior engineering institution. An engineering degree or equivalent would be an advantage and a background of technical work is desirable.

Salary : £860 (at age 25)–£1825 p.a., according to experience.

Housing and superannuation schemes.

Please send POSTCARD for application form to the Group Recruitment Officer (1581/25), U.K.A.E.A., Atomic Energy Research Establishment, Harwell, Didcot, Berks.

E8969 A

APPLICATIONS ARE INVITED from ambitious and resourceful men to fill the position of TECHNICAL ASSISTANT to the Sales Manager of Electric Lamp Machinery Manufacturers near London. A permanent progressive and interesting job is offered to the right person, who must possess a sound engineering and commercial background in the trade.—Applications, with full particulars of education, experience and salary required, to BOX No. E171, "The Engineer." A

BRITISH INSTITUTE OF MANAGEMENT

require a

PRODUCTION MANAGEMENT ADVISER

Successful applicant will probably have served an engineering apprenticeship and be a Member of the I.Mech.E. or I. Prod.E. Duties will be varied and extremely interesting. The post offers scope to a first-class man who may wish to return to industry in about 4 years' time or to an older man as a permanency.

The work will cover management aspects of production control, planning, work study, maintenance and quality control ; experience in one or more of these fields is essential.

Advisers have to provide information and advice to enquirers and are responsible for the content of courses and conferences on subjects related to production management. They will have the use and assistance of a library and Advisory Committee.

Starting Salary : £950–£1050. Pension Scheme. Applications to Mr. N. Gallagher, Head of Management Services Dept., British Institute of Management, 80, Fetter Lane, London, E.C.4. E8984 A

CENTRIFUGAL PUMP DESIGNER required for South East England. Applicants must be experienced in modern Pump Practice and High Specific Speed Axial and Mixed Flow Designs.—Applicants should give details of age, experience and salary required to BOX No. E8756, "The Engineer."

CHIEF APPLICATIONS ENGINEER required by a leading manufacturer of small high-speed air- and water-cooled diesel engines. The position is a senior one and carries technical responsibility for all the company's products after the development stage. The successful applicant will have had senior experience in all major branches of diesel engineering, and be capable of controlling large sales liaison and drawing office staffs. Contributory pension scheme. —Apply BOX No. E9048, "The Engineer." A

CHIEF DESIGNER.—At Duramin we design and build bodywork for a wide range of specialised commercial road vehicles and our product is nationally known for quality. We require a man of extensive engineering experience, both practical and theoretical, to take over control of the drawing-office, with responsibility, after training, for bodywork design, answering to the technical directors and collaborating with sales and project engineers. This is a senior post, offering great interest and variety in an enthusiastic, happy and growing company, where conditions are excellent and where initiative, ability and hard work are recognised.—Write in confidence to Production Director, Duramin Engineering Co., Ltd., Stonefield Way, Ruislip, Middlesex. E2719 A

DRAUGHTSMAN

Applications are invited for the above post, which is located in Birmingham.

The work is interesting and varied and is mainly in connection with the design of industrial heating equipment. A knowledge of combustion technique and the use of refractories would, therefore, be an advantage.

Candidates should possess the Ordinary National Certificate in Mechanical Engineering as a minimum qualification.

The salary for the appointment, which is pensionable and subject to medical examination, will be within the range of £733–£853 per annum.

Applications, stating age, qualifications and experience, together with the names of two referees, should be addressed to the Industrial Relations Officer, West Midlands Gas Board, 6, Augustus Road, Edgbaston, Birmingham, 15. E180 A

DRAUGHTSMAN—age 25/30—required for varied chemical plant development work. H.N.C. (Mechanical) and knowledge of plant layout and pipe work essential. Permanent and progressive post. Superannuation and profit sharing schemes.—Applications to : Personnel Manager, Messrs. F. W. Berk and Co., Ltd., Abbey Mill Chemical Works, Canning Road, Stratford, E.15. E8990 A

BOOKS and PUBLICATIONS

A DIGEST OF ELEMENTARY CHEMICAL THERMODYNAMICS

By D. SHIREBY, A.R.I.C.

This book provides an elementary account of chemical thermodynamics suitable for students in the earlier years of technical college and university courses and in the sixth forms of grammar schools. The mathematics involved are fairly easy and the text includes many worked examples. Price 20s. net.

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By A. BANNISTER, M.C., B.Sc., etc., and E. S. RAYMOND, B.Sc., etc.

A new textbook for the examinations of the H.N.C. and Diploma in Civil and Structural Engineering and in Building ; I.C.E., Part II ; R.I.C.S.,; Dip.Tech. and Degrees in Engineering. It provides a direct approach to the subject and covers modern instruments and techniques. Engineering Degree Series. Price 45s. net.

FUNCTIONS OF COMPLEX VARIABLES

By PHILIP FRANKLIN

This book is outstanding for its clear and precise explanation of a branch of mathematics which has often been obscured in a haze of highly abstract concepts. Logical and essentially complete, its purpose is to introduce the reader to the general properties of an analytical function of a single complex variable. Price 25s. net.

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1960

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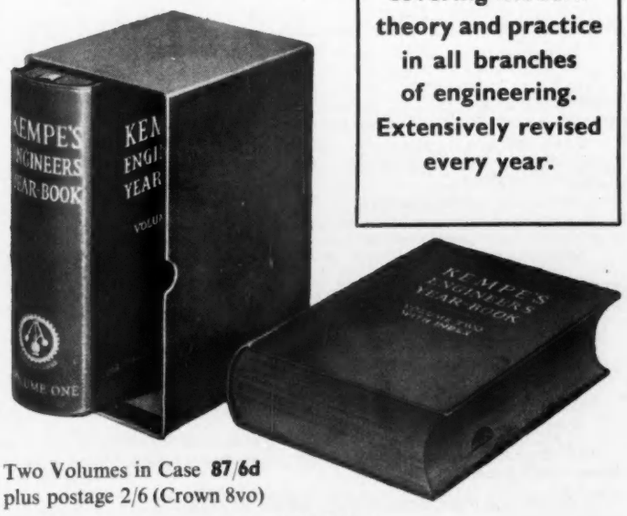

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SITUATIONS VACANT

DEPUTY CHIEF INSTRUMENT ENGINEER

required for large group of Chemical Companies. Headquarters will be in London and duties will involve advising Works Managements on instrumentation problems, controlling Graduate Engineers on design work, supervising instrument erection and deputising for the Chief Instrument Engineer. Factory experience essential, design experience desirable.

Age approximately 35 years.

Salary commensurate with responsibility.

Non-contributory pension scheme is in operation.

All replies to the Appointments Secretary, Box D.C.1969, A.K. Advg., 212a, Shaftesbury Avenue, W.C.2.

E9037 A

DESIGNER/DRAUGHTSMEN required, for hydraulic and pneumatic valves. H.N.C. standard. Isleworth area. Applications, with full details and salary required.—BOX No. E8844, "The Engineer." A

DRAUGHTSMAN required by Gilbert Gilkes and Gordon, Ltd., for work on design of turbines, pumps and associated hydraulic equipment. Good working conditions—canteen, pension scheme and bonus scheme in operation.—Apply, giving full particulars, to Chief Draughtsman, Gilbert Gilkes and Gordon Ltd., Kendal, Westmorland. E8998 A

DRAUGHTSMEN required for Design and Development Work on Pneumatic and Electric Portable Power Tools. Interesting work, progressive and permanent positions. N.W. London area. —State age, experience and salary required to Head Designer, BOX No. E9045, "The Engineer." A

DUE TO EXPANSION A FEW VACANCIES OCCUR FOR DESIGN DRAUGHTSMEN with Bratby & Hinchcliffe, Ltd., Gorton Lane, Manchester, 18, on specialised automatic machinery. Pension scheme, welfare facilities, canteen, &c.—Apply by letter to Managing Director stating qualifications, present salary, age, experience, &c. E2732 A

DUNLOP RUBBER CO. LTD., Manchester, has a vacancy for a TECHNICAL ASSISTANT with engineering background, for development and design work on a wide range of rubber products. Age 20–30 years. Training to approximately Ordinary National Certificate level in Mechanical Engineering would be an advantage and preference will be given to applicants with a good working knowledge of engineering drawing. Salary would be commensurate with ability, initiative and readiness to accept responsibility. The position offers wide scope for advancement in a rapidly expanding branch of the industry.—Applications should be addressed to Technical Personnel Officer, Dunlop Rubber Co., Ltd., Cambridge Street, Manchester, 1. E8989 A

EDITORIAL ASSISTANT required for monthly journal specialising in world hydro-electric development. Should be young engineer (25–35), with qualifications and experience preferably in civil or hydraulic engineering or in laboratory work. Aptitude for technical writing essential. Some knowledge of languages an advantage. Prospect of eventual editorship for the right candidate.—Apply ; The Editor, "Water Power," 33, Tothill Street, S.W.1. E9040 A

ELECTRICAL ENGINEER

If you have a good honours degree in Electrical Engineering, are aged about 30, and would like to join the Commonwealth's largest glass manufacturing organisation, you are invited to write personally to Dr. W. L. Patrick, General Manager, Pilkington Brothers, Limited, Kirk Sandall, Doncaster, where there is a £4,000,000 capital development programme.

You would be an Assistant Electrical Engineer in a department responsible for the design and maintenance of a wide range of electrical equipment and instrumentation required for the supply and operation of large-scale continuous processes.

Interviews are being arranged for the week commencing 14th March.

E9008 A

ENGINEER (MECHANICAL).—Applications are invited from Engineers not over 35 years, who possess 1st Class M.O.T. Certificates (Steam). Willing to reside in or near London for duties in that area and to undertake three-monthly tours of inspections of boilers, pressure vessels, &c., in West Africa. Salary in accordance with age, previous experience, if any, plus expenses and allowances. Non-contributory pension scheme. Apply in own handwriting.—BOX No. E8820, "The Engineer." A

GENERAL WORKS MANAGER

(with prospects of early promotion to the Board) for medium-sized Engineering Company in London, to take charge of Production Departments manufacturing machines for Printing and allied trades and to give technical advice on the development of new products.

Applicants aged 30–45 should be good organisers and have had experience with an Engineering Company manufacturing capital goods. A Mechanical Engineering Degree or equivalent is essential.

Starting Salary £2000 per annum, plus bonus —Pension Scheme, &c.

There are excellent prospects for an ambitious man to earn a seat on the Board and to grow with the Company, which has plans for expansion and the finance necessary to carry them out.

Please send full details, including age, experience and present salary.—BOX No. E8979, "The Engineer."

ENGINEER SALESMAN required for London area Well-educated. Mechanical Engineer. Not more than 38 years of age. Required to sell pipework and general engineering products. Energetic and adaptable personality. Must have selling experience.—BOX No. E2736, "The Engineer." A

ENGINEERING, PHYSICS AND SCIENCE GRADUATES or equivalents required for new appointments involving research, design and development work on : (1) Dynamic behaviour of machine tools and problems associated with automatic control ; (2) Press working processes, cold extrusion and other new techniques for the forming of metals ; (3) Machining processes ; initially work will be concerned with the appraisal of new machining developments or studies of machining costs on a comprehensive scale ; (4) Mechanical engineering equipment, including special machine tools, presses, mechanisms, test rigs, &c. Successful candidates will be expected to take complete responsibility for projects from conception to completion. Capacity for creative thinking and initiative are important. The conditions of employment are attractive and there are excellent prospects for advancement. Superannuation scheme. Removal expenses paid.—Send full details in confidence to the Secretary (R.650), Production Engineering Research Association, Melton Mowbray, Leics. E8944 A

ENGINEERS required for service in West Africa by a company within the Unilever Group, operating Palm Oil Estates. Age limits 26–32. Experience should include responsibility for staff, operation of boiler plant, steam and I.C. engines, electrical installations and transport. Appointment is one of responsibility for efficient operations of all estate plant and equipment, also control and training of African staff. Minimum qualifications, Graduate M.I.Mech.E. or equivalent. Electrical qualification an advantage. Salary not less than £1500 per annum, depending on experience. In addition there are family allowances and free furnished accommodation and contributory pension fund. Apply in writing, stating age, education, qualifications and experience. —BOX No. E8995, "The Engineer." A

HEATING AND VENTILATING INTERMEDIATE DRAUGHTSMAN required, age not exceeding 26 years, with experience in the general design and estimating of all types of private and industrial heating systems. Good salary, L.V. and bonus and pension scheme. Holiday arrangements honoured. Good prospects for the right man.—Write, giving age, experience and salary expected, to the Secretary, Carrier-Ross Engineering Co., Ltd., 22A, Cavendish Square, London, W.1. E2735 A

'HEINZ'

Leaders in the expanding Food Industry offer the following vacancy for a

JUNIOR MECHANICAL ENGINEER—aged 22–28, to assist the Manager—Mechanical Engineering—in the administration of contracts placed for new projects throughout the Company, and other work normally handled by a Head Office Engineering Department. H.N.C. preferred, with some experience of project engineering for the process industries. This is a permanent and progressive position, offering considerable scope for the exercise of initiative.

Please write fully to the Personnel Officer, H. J. Heinz Company Limited, Waxlow Road, Harlesden, London, N.W.10. E8999 A

IMPERIAL CHEMICAL INDUSTRIES LIMITED has a vacancy for a TECHNICAL ASSISTANT for its Standards Section in London for work relating to engineering plant and general stores equipment. Candidates must hold the Higher National Certificate or equivalent qualification and have had practical and drawing office experience. As the duties of the post include liaison and committee work candidates must have first-class personal qualities and be able to express their ideas clearly and concisely.—Applications, giving age and experience, should be made to Head Office Staff Department (GDC), Imperial Chemical House, Millbank, London, S.W.1. E9031 A

MAJOR INDUSTRIAL COMPANY requires an ENGINEER at one of its North London Works. Applicants should have a good engineering background and preferably some experience in development work in a Process Industry. He will act as an assistant to the Engineering Manager and would be required to work both on new projects and modification of existing plant. Minimum qualification of Higher National Certificate and the age range is 24-30 ; an attractive commencing salary, and there are bright prospects for the future.—Please reply to BOX No. E9025, "The Engineer." A

MECHANICAL AND ELECTRICAL ENGINEER

RACKHAM'S NEW STORE DEVELOPMENT IN BIRMINGHAM.

A vacancy exists for a CHIEF ENGINEER who would be required to control staff engaged on plant operation and maintenance, and also be responsible for additions and replacements of machinery, equipment, &c. Minimum qualifications H.N.D. and A.I.Mech.E., or A.M.I.E.E. and sound practical experience with a large industrial concern. Permanent and pensionable position.

Applications, in writing, giving age and full details of experience, to Mr. A. Spence, Harrods Limited, Knightsbridge, London. E8994 A

MECHANICAL ENGINEER

If you have a good honours degree and Corporate Membership of the Institution of Mechanical Engineers, are aged about 35 and would like to join the Commonwealth's largest glass manufacturing organisation, you are invited to write personally to Dr. W. L. Patrick, General Manager, Pilkington Brothers, Limited, Kirk Sandall, Doncaster, where there is a £4,000,000 capital development programme.

You would be considered for a managerial position with a view to being appointed Deputy Mechanical Engineer in a year's time with positive prospects of further early promotion. You would be required to organise the construction, maintenance and development of highly mechanised continuous process plants presenting many varied and novel problems in all aspects of mechanical engineering.

Interviews are being arranged for the week commencing 14th March.

E9007 A

Classified Advts. continued on page 120

SITUATIONS VACANT

MECHANICAL ENGINEER. Opportunity occurs for Graduate or Corporate Member of the I.Mech.E., between 35 and 40 years of age, to assist in the Management of a large progressive old-established mass production engineering works in the North Midlands. The Company is of international repute with several factories and produces a high precision product. Candidates must have had first class production experience, possess personality and tact and be capable of fitting into and taking part in the management and production administration of a large modern organisation. Good opportunity for a candidate who can measure up to the above requirements. Good conditions and pension scheme.—Reply, stating age, and full particulars of experience and qualifications, and salary expected.—BOX No. E8976, "The Engineer."

NUCLEAR ENGINEERING

DEVELOPMENT ENGINEERS required for work on novel projects connected with nuclear and conventional steam-generating plant.

Applicants should preferably hold a mechanical or Chemical Engineering Degree and should have some previous experience of the practical aspects in design or development of heat exchangers and high-pressure steam plant.

Commencing salary in range £900–£1200 per annum. Contributory Pension Scheme.

Application should be made in writing, giving details of age, qualifications and experience, to :

Staff Manager,
Foster Wheeler Limited,
3, Ixworth Place,
London, S.W.3.

E9035 A

ONE SENIOR ELECTRICAL DRAUGHTSMAN with experience in the control of Crane and Hoisting and Machinery. Contributory Pension Scheme, Canteen.—Apply in writing, stating age, salary required, previous training and experience to Woodfield Rochester Ltd., Frindsbury Works, Rochester, Kent. E8926 A

PLANT ENGINEER

A qualified Engineer, experienced in installation and maintenance of medium heavy mechanical and electrical equipment, for Works in Birmingham area. This is a permanent Staff appointment and a Pension Scheme is in operation.—Applications should include full details of experience, age and indication of salary scale to BOX No. E2727, "The Engineer." A

PRODUCTION CONTROLLER required to take charge of Planning, Progress and Stores, in rapidly expanding light engineering works in South Warwickshire. A salary of £1000 and upwards will be paid for an experienced man possessing drive and initiative, capable of introducing modern planning and production control technique. The post is permanent with Pension Scheme. Housing can be arranged if necessary.—Write, giving brief outline, including age, technical qualifications, positions held, and salaries earned, to BOX No. E2729, "The Engineer." A

PRODUCTION ENGINEER for a Heavy Engineering Works in E. London. First class opportunity for a man of proven ability with extensive experience in Work and Method Study and Incentive Payment Schemes as applied to small batch and jobbing production of large units. Applicants should preferably be qualified engineers, age 30-40. Salary commensurate with experience and qualifications, but not less than £1200 per annum. Applications in strict confidence, stating full personal particulars, experience and present salary.—BOX No. E9041, "The Engineer."

A

PUMP ENGINEER required by Contracting Company to the Petroleum and Chemical Industries. Applicants should preferably have a University degree in Engineering, together with at least five years' experience in the design and manufacture of both reciprocating and centrifugal pumps. Some experience with steam turbines and other drivers is also desirable but not essential. Generous salary will be offered to the right type of man with the necessary experience and qualifications.—Please write, stating briefly age, qualifications and experience to BOX No. 3025, c/o Charles Barker & Sons, Limited, Gateway House, London E.C.4. E9014 A

QUARRY MANAGER WANTED TO SERVE IN PAKISTAN

Pakistani firm requires a competent Aggregate Plant Manager to serve in Pakistan for two years. Must be qualified person between 30-50 years of age with experience of Quarries and Aggregate Plants.

Attractive terms of payment commensurate with suitability.—Apply, stating full particulars, including age, education and experience, terms acceptable and enclosing recent photograph and health certificate to Omar Sons, Limited, Spencer's Building, McLeod Road, Karachi.

E9033 A

SALES ENGINEER for manufacturing company of international repute connected with the oil industry. There will be a training period. Applications are invited from young Engineers of good presence and address, either University training or with H.N.C. Only those with the required qualifications should apply. Excellent prospects. Write fully.—BOX No. E8894, "The Engineer." A

RICHARD THOMAS & BALDWINS LIMITED

A GENERAL MANAGER

is required for a Subsidiary company engaged in the development and operation of large ironstone quarries. Applicants should be qualified mining or civil engineers with particular experience in charge of open-cast mining operations involving the use of heavy plant and equipment.

The successful applicant will be responsible for operational control and development of the Company's affairs. He should have had experience of general administration, including a working knowledge of costing and accounting procedures.

A vacancy also occurs for a qualified CIVIL ENGINEER who will be responsible to the General Manager for the engineering work involved in the operation and development of these quarries. Applicants should have had good experience in the actual construction of civil engineering works, particularly roads, bridges and railways, and should be conversant with the installation and operation of large excavation plant and equipment.

Application Forms can be obtained from :

The Management Development Department,
RICHARD THOMAS AND BALDWINS, LIMITED,
47, Park Street, London, W.1.

E9005 A

SALES ENGINEER, with broad experience Buying and Selling Secondhand and New Machinery, West of England.—BOX No. E9001, "The Engineer." A

SALES EXECUTIVE is required by an expanding engineering organisation in the Newcastle-on-Tyne area with an established reputation for the manufacture of mechanical and hydraulic transmission products. The successful applicant will be required to advise the General Manager on sales problems ; to control sales administration ; to compile technical sales literature and to co-ordinate the activities of the sales force. This position calls for an energetic man of high calibre, aged 30-40 years, and preferably with a professional Engineering qualification supported by practical engineering experience. He should have a proven sales record, a keen interest in, and appreciation of sales administration, with a flair for technical sales publicity. He should be capable of advancement to Sales Manager in due course. Initial remuneration of up to £1700 p.a. Superannuation and house purchase schemes are in operation.—Apply in confidence.—BOX No. E8974, "The Engineer." A

SAO PAULO LIGHT S.A.—SERVICOS DE ELETRICIDADE, a company in Brazil and a subsidiary of the Canadian Corporation Brazilian Traction, Light and Power Company, Limited, invite applications from suitably qualified men for the position of SHIFT CHARGE ENGINEER in the Piratininga Power Station. The power station, put into service about five years' ago, is situated near Sao Paulo (population over 3 millions ; temperate climate ; 2200ft. above sea level). The plant comprised initially 2 × 80MW., 1800 r.p.m., steam turbo-alternator units, each supplied at 850 p.s.i., 900 deg. F., by one 850,000 lb/hour oil-fired boiler, and is now being expanded by the addition of two 125,000 kW. reheat units, 1800 p.s.i., 1000 deg. F. Applicants should have a sound technical knowledge and wide experience of the operation of modern turbines and boilers, preferably with oil or pulverised-fuel firing ; should also have an aptitude for supervision and the maintenance of harmonious labour relations. Good salary, three years' agreement with first-class passage both ways with family ; four months' paid leave after three years' service.—Written application in the first instance should be made to Mr. Osborne Mitchell, General Manager, CANADIAN-BRAZILIAN SERVICES LTD., 9/12, Cheapside, London, E.C.2. E8941 A

SENIOR DESIGN DRAUGHTSMAN

required with experience of Industrial Heating Furnaces as used in the iron and steel industry. Life Assurance and Contributory Pension Scheme.

Write to the Chief Engineer, Appleby-Frodingham Steel Company, Scunthorpe, Lincs, stating age and giving full details of experience.

E9032 A

SENIOR DESIGN ELECTRICAL ENGINEER required by company manufacturing Industrial Trucks. Responsibility involves design and test of electrical apparatus for traction and equipment drives and development of same. Knowledge of electronics desirable. Previous experience of similar work essential. Remuneration will be in keeping with responsibility. Applications, stating age, qualifications and experience.—BOX No. E8993, "The Engineer." A

SENIOR DRAUGHTSMAN for progressive firm producing Pressure Vessels and similar equipment for Chemical and Petroleum Industries. 5-day week. Canteen and recreational facilities. Excellent conditions. Staff superannuation scheme. Good salary to a fully experienced candidate.—Telephone : MARyland 3214. E2734 A

TECHNICAL SALES REPRESENTATIVE, operating from central London Office, required for medium-sized Engineering Company with factory in Devon. The position entails technical liaison work in connection with high performance gearboxes for Industrial, Marine and Vehicle applications. Applicants, who should be educated to H.N.C. standard and have had gear experience, must also possess initiative, and the capacity for hard work. Generous salary and pension scheme.—Apply : Personnel Officer, Centrax Ltd., Shaldon Road, Newton Abbot, Devon (Quote SAR/100). E2730 A

WANTED, FIRST-CLASS SENIOR DESIGN DRAUGHTSMAN for firm of General Engineers in Bristol. Good knowledge of general engineering, with particular reference to pressure vessels and stainless steel fabrication. This will be a well-paid position for the top-class man.—BOX No. E164, "The Engineer." A

WEST MIDLANDS GAS BOARD
ASSISTANT ENGINEER
CHIEF ENGINEER'S DEPARTMENT

Applications are invited from competent Site Engineers for the post of Assistant Engineer to oversee and control the erection of the new Lurgi complete gasification plant, which is being erected with ancillaries at Coleshill, Warwickshire, at a cost of £8,000,000.

Experience in supervising large contracts covering civil, structural and mechanical engineering will be an advantage, whilst Membership of the Institution of Civil Engineers or a similar body is desirable.

The salary for the appointment, which is pensionable and subject to medical examination, will be within the range of £1195 to £1355 per annum.

Applications, stating age, qualifications and experience, together with the names of two referees, should be addressed to the Industrial Relations Officer, West Midlands Gas Board, 6, Augustus Road, Edgbaston, Birmingham, 15.

E9023 A

WORKS MANAGER required for well-known Company in India, manufacturing diesel engines under licence, to take charge of complete production from foundry to final testing. Modern factory. Excellent Salary and free accommodation. Car provided. Two-year contract. Free Air travel.—BOX No. E8975, "The Engineer." A

JOHNSON, MATTHEY & CO., LIMITED.

DESIGN ENGINEER

Aged 23-33, with good drawing-office background, is required for the Chief Mechanical Engineer's office in Central London. A sound practical training and knowledge of engineering services is essential.

The work entails handling projects from the drawing-board through to construction and running in for production.

Conditions of service include free lunches and an annual bonus, also a contributory pension scheme.

Write, giving full details of age, qualifications, experience, &c., to the Secretary, Johnson, Matthey & Co., Limited, 78, Hatton Garden, London, E.C.1.

E9002 A

AIR PRODUCTS (G.B.) LTD.

have vacancies for

PROJECT MANAGER

A qualified Chemical or Mechanical Engineer with experience as Project Engineer in the chemical plant field. Experience in low temperature engineering is desirable but not essential.

DEVELOPMENT ENGINEER

A qualified Chemical or Mechanical Engineer for appraisal of new techniques, equipment design, the study of materials and preparation of standards, etc.—all associated with the design, construction and operation of low temperature plants.

STANDARDS ENGINEER

Graduate H.N.C. (Mech.) minimum, with experience as a Standards Engineer in the Chemical and Process Plant Industry. To originate and prepare engineering standards for use in the Design Department and other engineering facilities of the Company on request, and to develop these standards into a comprehensive manual on his own initiative. Must be able to develop fully design standards for all aspects of pressure vessel, piping and mechanical design for ferrous and non-ferrous applications. Experience of high pressure and high temperature systems is advantageous, together with a knowledge of valves and flange systems. Must possess leadership potential to develop a fully integrated Standards Group.

Write

PERSONNEL MANAGER,
49-50, POLAND STREET,
LONDON, W.1.

E9020 A

GLACIER METAL COMPANY LTD., KILMARNOCK.

We are an expanding and vigorous organisation and offer interesting and rewarding work to well-qualified and experienced Engineers who have a lively outlook and potentiality for further advancement.

Internal promotions and the need for additional staff give rise to the following vacancies :

PRODUCTION ENGINEERS.

Production Engineers are required for the Engineering Departments of Production Units engaged in the manufacture of plain bearings, bushes and centrifugal oil filters. The work embraces a wide range of production engineering activities and involves the exercise of initiative and acceptance of responsibility.

An Engineering Degree and/or membership of the Inst.Mech.E. or Inst. Prod.E. are preferred qualifications and considerable experience of Production Engineering in the light precision engineering field is desirable.

Salary range : £950–£1350 per annum.

There are also vacancies for **Junior Production Engineers** and **Design Draughtsmen,** whose work initially would be concerned with Planning and/or Jig and Tool design.

An engineering apprenticeship and technical training to H.N.C. level are the qualifications required and experience should include production planning or jig and tool design, particularly in the light precision engineering field.

Salary range : £15 15s. 0d.–£17 0s. 0d. per week.

WORK STUDY ENGINEERS.

Additional **Work Study Engineers** are required for our expanding Work Study Dept., where emphasis is laid on work study rather than time study. One engineer would be stationed at a subsidiary factory in the Glasgow area.

Minimum qualifications are H.N.C., thorough training in Work Study techniques and at least 2 years' practical experience in their application.

Salary range : £950–£1350 per annum.

All of these appointments are progressive and there are excellent prospects for future advancement.

The factory is a modern one, situated close to the holiday resorts on the West Coast of Scotland.

Applications for any of these vacancies, containing brief details of age, qualifications, experience and present salary, to E. C. Goldring, Personnel Manager, Glacier Metal Co., Ltd., Kilmarnock, Ayrshire.

E9016 A

SITUATIONS VACANT

Opportunities for Graduate Engineers

IN CHEMICAL AND MECHANICAL ENGINEERING

Have YOU a B.Sc. or higher degree and one to five years' experience in process or power plant engineering design, full scale or pilot plant operation, process technical service or related activities?
Are YOU interested in working in all categories of Refinery and Chemical Plant design and in broadening your experience and prospects for advancement? If so, we would be glad to hear from you. A number of engineers are required for the enlargement of our Engineering Design Office. The positions offered allow scope for individual initiative and carry salaries fully commensurate with age and experience, together with pension scheme and expenses paid for moving if engaged from outside London. These career opportunities are for men of the highest calibre interested in a large, expanding organisation engaged in worldwide engineering and construction work.
Comprehensive personnel benefits include contributory pension scheme, luncheon vouchers, excellent working conditions and social club.

Please write to Mr. R. H. Paterson

KELLOGG INTERNATIONAL CORPORATION,
7-10 CHANDOS STREET, LONDON, W.1

E8966A

SITUATIONS VACANT

A. MONK & COMPANY, LIMITED, WARRINGTON, LANCS.

REQUIRE SITE ENGINEERS for major projects in and around the North Western, North Eastern and South West Midland areas. Permanent and progressive posts. Superannuation Scheme in operation. Applications in confidence stating age, full details of experience and qualifications, etc.—Please reply to Mr. H. Hudson, Personnel Department, A. Monk & Company, Limited, Padgate, Warrington, Lancs.

E8872 A

SITUATIONS VACANT

ASSISTANT WORKS MANAGER

The Works Manager of a progressive Light Engineering Company in the London area is seeking to appoint a qualified assistant to relieve him of some of the day-to-day problems of batch production.

The ideal person will be in his mid-thirties and should have had some years' experience in shop management. His earlier background should include sound practical and theoretical engineering training, with a toolroom apprenticeship preferred. He must possess drive and enthusiasm and be capable of giving a sound technical lead to production and maintenance foremen.

A good salary is offered and the position is pensionable and offers excellent prospects. —Please write full details of age, experience, &c., in confidence, to BOX No. E9049, "The Engineer."

A

THE REED PAPER GROUP

Reed PAPER GROUP

requires an

INSTRUMENTATION ENGINEER

Applications are invited from qualified men aged between 30 and 40 years, for a senior appointment in the Process Development Section of the Packaging Division Development Department at New Hythe, near Maidstone, Kent.

The successful applicant will be responsible for the development and design of control and recording equipment for paper conversion purposes. Sound practical experience on the design and application of electrical, hydraulic, pneumatic and electronic devices to automatic process control is essential; therefore, only men of proven ability need apply.

The salary will be commensurate with the qualifications and experience required. A non-contributory pension scheme is operated and assistance with house purchase is available if required.

Write for application form to:

The Group Personnel Officer, Group Office Building,
Albert E. Reed & Co., Ltd.,

Larkfield, Nr. Maidstone, Kent., quoting reference number IE PDDD 71.

E8991 A

AEI

ASSOCIATED ELECTRICAL INDUSTRIES LIMITED

SENIOR MECHANICAL ENGINEER

The Large Electrical Machine Engineering Department of the Heavy Plant Division in Manchester requires a Senior Mechanical Engineer. This is a responsible position concerned with the mechanical design and development work involved in the electrical design of large rotating plant for hydro-power stations and general industrial applications. A laboratory is available to facilitate experimental work.

It would be desirable for applicants to have had previous experience of this type of work, but a first class engineer, with sound mechanical knowledge, would be favourably considered. It is expected that persons possessing the required background would be aged 30 years or over.

QUALIFICATIONS: Applicants should have served a recognised engineering apprenticeship, and preferably hold a degree in Mechanical Engineering. They should be at least an Associate Member of the Institution of Mechanical Engineers.

Please write for application form quoting reference O.14 to:
The Personnel Manager,
ASSOCIATED ELECTRICAL INDUSTRIES (MANCHESTER), LTD.,
TRAFFORD PARK, MANCHESTER, 17.

E8964 A

CENTRAL ELECTRICITY GENERATING BOARD

RESEARCH AND DEVELOPMENT DEPARTMENT
APPLICATIONS BRANCH (MECHANICAL)

DESIGN ENGINEERS Ref. ENR/74

The Design Section of the Applications Branch is in process of selecting a small team of competent Design Engineers. This team, supported by a Drawing Office, will be responsible for the engineering design of development projects of advanced technical interest and will be **LOCATED AT GUILDFORD POWER STATION.**

A Senior supervisory post is available for a man of special ability.

The Section designs special purpose experimental apparatus and test rigs of a substantial scale, covering a wide range of mechanical, electrical and electronic engineering. This work requires the collective efforts of a team of Design Engineers, each having the basic technical knowledge and mental agility to acquire an understanding of the underlying processes, and able to make his own contribution of originality and sound engineering in furthering novel projects in collaboration with specialising engineers and physicists. These novel projects will require the use of new materials and constructional methods.

Applications are invited from Engineers of some years' experience in research or development, who possess sound technical capability and find genuine interest in using their knowledge and originality to overcome the problems arising in new developments. They should preferably possess an Engineering Degree. Experience and interest should lie in the fields of steam raising, combustion, fuel handling, chemical engineering, electrical equipment or electronic instrumentation.

The salary for the senior supervisory post will be on a scale within the range £1,530 to £1,985 p.a. according to duties and responsibilities.

Salaries for the Design Engineers will be on scales within the range £850 to £1,775 p.a. according to duties and responsibilities.

CHEMISTRY AND METALLURGY DIVISION
METALLURGY SECTION

METALLURGIST Ref. ENR/48

required in the above section at the **RESEARCH LABORATORIES, LEATHERHEAD, SURREY,** to work on problems associated with fuels and canning materials for nuclear power stations.

Candidates must have an honours degree or equivalent qualification in metallurgy and experience in physical metallurgy is desirable.

Salary on a scale within a range rising to £1,300 p.a.

Applications, stating age, qualifications, experience, present position and salary, to the Personnel Officer, 24/30, Holborn, London, E.C.1, by 7th March. Envelopes should be marked "Confidential," quoting relevant reference number. E9019 A

ENGLISH ELECTRIC

(Whetstone Near Leicester)

offer opportunities to

DRAUGHTSMEN

1. **ELECTRICAL and MECHANICAL** — for work on remotely controlled and automatic machinery for the control and fuelling of Nuclear Power Stations.

3. **PLANT LAYOUT** — for work on the layout of Power Station plant and associated reactor plant.

These appointments require applicants to have a Higher National Certificate and several years' D.O. experience (preferably in a similar field, but this is not essential). Candidates with O.N.C. and particularly relevant experience would be considered.

The Company offers good working conditions in rural surroundings. The appointments are permanent and pensionable and assistance towards housing can be considered.

In replying please give details of experience, qualifications and current salary. Correspondence should be addressed to Dept. C.P.S., Marconi House, 336-7, Strand, London, W.C.2, quoting reference E1899K.

E9038A

Classified Advts. continued on page 122

SITUATIONS VACANT

MSL *have been retained to advise on the appointment of a*

BODY ENGINEER

(Motor cars)

for a leading manufacturer of motor vehicles.

He will be responsible to the Chief Body Engineer for the design of new bodies for motor cars and improvements to existing bodies.

Candidates must hold a degree or its equivalent in Mechanical Engineering with a specialised knowledge of structures where lightness combined with stiffness is all important. A knowledge of the capabilities and limitations of presses and of the latest manufacturing techniques is essential.

Age 35 to 45. Salary according to experience but not under £2,000. Contributory pension.

Please send brief details in confidence, quoting reference G.2202, to H. A. P. Disney. In no circumstances will a candidate's identity be disclosed to our client unless he gives permission after a confidential interview at which he will be given full details of the appointment.

MANAGEMENT SELECTION LIMITED
17, Stratton Street, London, W.1.

E135 A

SITUATIONS VACANT

PRODUCTION ENGINEER

A well-known Company north of London, engaged on the production of medium to heavy civil engineering equipment, wishes to appoint a Production Engineer. The position would carry responsibility for production methods and for advising the General Manager on plant improvements. Age range 30–40 preferred and applicants should have a wide experience of this type of work, with technical qualifications up to the level of Higher National Certificate. A commencing salary will be paid in the region of £1,200 p.a.—BOX No. E8963, "The Engineer."

A

SITUATIONS VACANT

PROJECTS MANAGER

We are one of the largest engineering contractors in the Oil and Petrochemical industries and due to expansion a vacancy has arisen for a Projects Manager.

We are seeking the services of a man of proved administrative ability, who has an appropriate chemical or mechanical qualification and with experience of controlling major projects from initial design through to commissioning.

Applicants should already command a salary of at least £2,500 p.a. and should address their applications giving full details of age, present and previous positions, in strict confidence to the Managing Director, BOX No. E9010, "The Engineer."

A

ANOTHER OPPORTUNITY IN IRON AND STEEL

BISRA

SENIOR METALLURGIST

The Steel User Section of the Association at Sheffield is shortly to commence an important project concerned with the compilation of data on the En Series of steels. For this interesting and worthwhile venture it is intended to engage a senior metallurgist, of some repute in the Steel Industry, who has an interest in such matters, and has a long and intimate knowledge of steel and its properties.

The position might well be filled by a recently retired metallurgist with the necessary additional qualities of diplomacy and ease of communication throughout industry.

Starting salary up to £1650 p.a. Written applications only, quoting "S.U.6." to Personnel Officer, The British Iron and Steel Research Association, 11, Park Lane, London, W.1.

E8965 A

LARGE COVENTRY FIRM

require

HYDRAULIC

and

MECHANICAL ENGINEERS

Successful applicants will be required to supervise their project from drawing board, through development, to production. Excellent office conditions, superannuation scheme and welfare facilities. Write, stating full details of experience, age and qualifications, &c., to BOX No. E8972, "The Engineer."

A

Projects Engineer

required by the

UNITED KINGDOM ATOMIC ENERGY AUTHORITY

PRODUCTION GROUP

to be responsible to a Chief Projects Engineer at the Group Headquarters, Risley, near Warrington, Lancashire, for the execution of major capital projects which involve provision of new chemical plants or fuel element manufacturing plants and also for major improvements and extensions to existing plants. The work includes the preparation of the case for financial approval and the specification of work required, and approval of the main engineering features of design.

A sound knowledge of mechanical and/or chemical engineering design and construction is required.

Applicants should possess an engineering degree or hold corporate membership of the Institution of Mechanical or Chemical Engineers.

Salary will be not less than £2,400 according to qualifications and experience. Contributory superannuation. Housing will be available.

Send postcard for application form, quoting reference P.133/71 to :

Group Staff Manager,
U. K. A. E. A.,
Production Group H.Q., Risley, Warrington, Lancs.

Closing Date : 7th March, 1960.

E8967 A

TUBE INVESTMENTS

RESEARCH AND DEVELOPMENT DIVISION

Tube Investments invite applications for appointment to the Scientific and Engineering Staff of their Technological Centre in Aldridge, Staffordshire. Applicants should be in the age range 24 to 35 years and possess an Honours Degree or its equivalent. Previous industrial experience is desirable but not essential.

Staff are required for process research and engineering development in the following fields :—

1. **Metallurgy,** with particular reference to beryllium and other "nuclear" metals, including cermets.
2. **Electronics,** with particular reference to new techniques of inspection based on eddy current and ultrasonic measurement.
3. **Electrical Engineering,** with particular reference to automatic control mechanisms using transistor and other electronic circuits.
4. **Welding,** with particular reference to development of new techniques for welding.

The salary offered will be in accordance with age and experience and applications should be addressed to The Director, T.I. Technological Centre, The Airport, Walsall, Staffordshire.

E8987 A

PILKINGTON BROTHERS LIMITED

GLASS MANUFACTURERS

SENIOR DRAUGHTSMEN

Senior Draughtsmen are required at Cowley Hill Works to work on the design and installation of new plant and associated services.

Applicants should have at least Higher National Certificate, and have had considerable experience on the design of special purpose heavy machinery or of general plant layout.

The position offers good prospects of promotion. The Company provides assistance with house purchase.

Applications should be addressed to the Works Personnel Officer, Pilkington Brothers Limited, Cowley Hill Works, St. Helens, Lancashire.

E8977 A

SITUATIONS VACANT

METALLURGICAL CHEMIST

is required by

W. H ALLEN SONS & CO., LTD.,

to take charge of the Chemical Section of the Metallurgical Laboratory at their Queens Engineering Works, Bedford. Applicant should possess at least H.N.C. and have experience in ferrous and non-ferrous analysis. A knowledge of corrosion and Works processes, i.e. electro-plating, an advantage. The work, which is varied and interesting, includes the training of junior staff. (Ref. 1601/D1/2.)

METALLOGRAPHER

is also required,

to take charge of a Section of the above-mentioned Laboratory dealing with micrography and photography, including the investigation of unusual service failures. A knowledge of works processes, such as welding, metal spraying, hard surfacing, etc., would be an advantage. Ability to write clear and concise reports essential. (Ref. 1601/D2/2.)

Permanent appointments with a good Staff Pension and Life Assurance Scheme. Apply, stating age and experience (quoting reference No.), to the Personnel Manager, W. H. Allen Sons & Co., Ltd., Bedford.

E8901 A

SITUATIONS VACANT

MECHANICAL ENGINEER

Position of senior responsibility for Engineer of H.N.C. standard or above and preferably having A.M.I.Mech.E. qualification ; of age up to 45 years and with proved ability to direct work of other technicians.

Mechanical development of our mobile generating plants is principally involved and successful experience of high-speed rotating machinery is essential. Of equal importance is ability to programme technical work effectively and then to promote compliance in both quantity and quality.

Progressive responsibility is envisaged, with suitably realistic reward. Applications will receive strictly confidential appraisal by Technical Director.

VERNONS INDUSTRIES LIMITED,
Kirkby Industrial Estate,
LIVERPOOL.

E9047 A

SITUATIONS VACANT

T.I. (GROUP SERVICES) LIMITED

(The Service Company of the Tube Investments Group)

A number of vacancies are available in the Plant Development Department of the above company for experienced

DESIGN ENGINEERS

The work of the department includes a wide range of plant design, development of prototype machines, factory planning, progressing installation programmes, etc.

PROMOTION

Excellent opportunities exist for promotion to responsible positions in the manufacturing companies of the Group. Pension Scheme and Life Assurance Scheme. Social Club facilities.

Applications are invited from men 28-35 years of age with experience in the design of special purpose machines and having as a minimum qualification Higher National Certificate or the equivalent. They should be sent, giving full details of qualifications, experience, present salary, etc., to the

Personnel Manager,
T.I. (GROUP SERVICES) LIMITED,
Rocky Lane, Aston,
Birmingham, 6.

E9018 A

FOR HIRE

LATTICE STEEL ERECTION MASTS (light and heavy), 30ft. to 150ft. high, for immediate hire.—Bellman's, 21, Hobart House, Grosvenor Place, S.W.1. E103 K

600
FORK LIFT TRUCKS
FOR HIRE

Modern Machines Only
Diesel & Battery/Electric
Capacities 2000 lb–18,000 lb.
Contact your nearest Depot :

GEORGE COHEN,
SONS & CO. LTD.
WOOD LANE, LONDON, W.12.
(Shepherds Bush 2070)

And at Stanningley (Nr. Leeds) . Kingsbury (Nr. Tamworth) . Manchester . Glasgow Swansea . Newcastle . Belfast . Sheffield Southampton . Bath

E200 K

PATENTS

THE PROPRIETOR of British Patent No. 742,957, entitled " DIAMOND DRESSING TOOL," offers same for Licence or otherwise to ensure practical working in Great Britain.—Enquiries to Singer, Stern and Carlberg, 14, E. Jackson Blvd., Chicago 4, Illinois, U.S.A. E8904 H

AGENCIES

AGENT WANTED for progressive company manufacturing open type steel flooring, steel staircases, steel fabrications. London and Home Counties. Must have connections with nationalised industries, consultants, oil refineries and general engineering companies. Write, giving full details.—BOX No. E2724, " The Engineer." D

AGENTS (ENGINEERS) required to help sell Sieving Plant to Chemical and other industries. Areas : Lancashire, N.E. England, Scotland. Minimum clerical work.—BOX No. E2737, " The Engineer." D

MACHINERY Etc. WANTED

ONE PLANING MACHINE, table 5ft. wide by 16ft. long, min. dimensions. Older type unit considered.—BOX No. E9046, " The Engineer." F

URGENTLY REQUIRED—One set of PLATE BENDING ROLLS, approx. size 8ft. to 10ft. by ¾in.—BOX No. E2739, " The Engineer." F

FOR SALE

IMMEDIATE SALE, near Kilmarnock. Two PENMAN ECONOMIC BOILERS, around 10,000 lb. evaporation each, 160 lb. pressure, with Hodgkinson Stokers, Economiser, pumps, grit and ash plant. Installed Government factory. Bargain price, £4000 where fixed.

FRED WATKINS (ENGINEERING) LTD.
COLEFORD, GLOS.

E179 G

" RUSHWORTH " ALL STEEL PRESS BRAKE, model 150/8, for sale. Capacity 8ft. by ¼in. Stroke 3in. Pressure 150 tons. Overall length of dies 114in. Arranged motor drive 400/440/3/50. Air operated clutch. Weight about 13¼ tons.—F. J. Edwards, Ltd., 359, Euston Road, London, N.W.1, or 41, Water Street, Birmingham, 3. E9042 G

FOR IMMEDIATE SALE to clear, 10-ton Heywood E.O.T. Crane, 3-motor, Cab Control. 32ft. 9in. span. 18ft. height of lift. With 208ft. of Gantry Track and 18 Stanchions. In good condition. £2,650 or near offer.—Full details BOX No. E107, " The Engineer." G

" RHODES " PRESS BRAKE, model 1036, for sale. Capacity 10ft. 6in. by 3/16in. thick. Pressure 150 tons. Stroke 3in. Distance between housings 8ft. 6in. Arranged motor drive 400/440/3/50. Bed and top beam of rolled steel sections.—F. J. Edwards, Limited, 359, Euston Road, London, N.W.1, or 41, Water Street, Birmingham, 3. E9043 G

LOCOMOTIVE (Diesel Shunting) by Hudswell Clarke, delivered 1957. 128 b.h.p., type 0-4-0. 4ft. 8½in. gauge. All flameproof construction. Little used. Offered for sale at considerably below cost.—BOX No. E8997, " The Engineer." G

HYDRAULIC PRESSES
HYDRAULIC PUMPS

Hydraulic Accumulators, Valves, Fittings, New and Second-hand. Complete installations.
All kinds of Hydraulic Equipment in Stock.
THOMPSON AND SON (MILLWALL), LTD.,
Cuba Street, Millwall, London, E.14.
East 1844/5. E111 G

NISSEN TYPE HUTS for sale. Prompt despatch of 16ft., 24ft., and 30ft. wide huts ; also " Romney " Huts, 35ft. wide, and " Blister " Hangars, 86ft. 6in. and 91ft. wide. These buildings are in various lengths and comprise steel framework with galvanised corrugated steel sheeting.—Full details from Dept. 115, J. Thorn and Sons, Ltd., Brampton Road, Bexleyheath, Kent. (Tel.: Bexleyheath 305). E113 G

" BESCO " HIGH DUTY GEARED GUILLOTINE for sale. Capacity 10ft. by 3/16in. Overcrank type with open ends. Automatic hold-down. Arranged for motor drive 400/440/3/50. Treadle clutch and all gauges.—F. J. Edwards Limited, 359, Euston Road, London, N.W.1, or 41, Water Street, Birmingham, 3. E9044 G

Classified Advts. continued on page 124

AIR CONDITIONING AND REFRIGERATION ENGINEER

A senior vacancy has arisen, due to expansion, for an Air Conditioning and Refrigeration Engineer, to erect and maintain plant of a leading American manufacturer in Dar-es-Salaam. Would be attached to leading British company in area.

Appointee should be not less than 30 years old, must have served five years' apprenticeship in the trade and have some years' field experience.

This opening would suit a practical engineer who is prepared to carry responsibility and make a career in Africa as a member of a British organisation. Above average terms of appointment. May be initially stationed for additional training in Salisbury, Southern Rhodesia.

Please write in the first place, with copies of testimonials, &c., to :

Box TE.791, c/o 191, Gresham House, E.C.2.

E9009 A

CHIEF DRAUGHTSMAN

required for Company engaged in the design and manufacture of Steam and Diesel Shunting Locomotives and General Engineering Work which includes Colliery Winding Engine Equipment. Applicants must have H.N.C. or equivalent and be capable of taking full charge of the Drawing Office. Preference will be given to applicants with experience of Locomotive Engineering. The position offers excellent prospects to the right man. Pension Scheme.

Write, giving details of experience, age and indication of salary expected, to The Director and General Manager, Andrew Barclay, Sons & Co., Ltd., Caledonia Works, Kilmarnock.

E8982 A

To all Draughtsmen (and Draughtswomen) seeking better opportunities for promotion and advancement

There's a future for YOU in the Walmsley Group of Companies

The Walmsley Group of Companies invite applications from qualified draughtsmen (and draughtswomen) for the drawing offices at each of the Group's five up-to-date factories at Bury and Wigan. The positions are permanent, progressive and well paid. Walmsleys is one of the world's largest Groups specialising in the manufacture of machinery and equipment for the paper-making industry which is constantly expanding in every country throughout the world. The work you will be engaged upon is varied and interesting and offers plenty of scope for men (and women) of proved ability. Applications from qualified men in advance of the normal age of employment will be fully considered. If you value a job in which you are sure of contentment, security and the co-operation and team-spirit of those working alongside you, then here is such an opportunity, make sure you take advantage of it by writing NOW.

SEND TO-DAY FOR THIS BOOKLET

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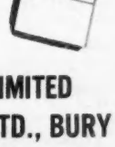

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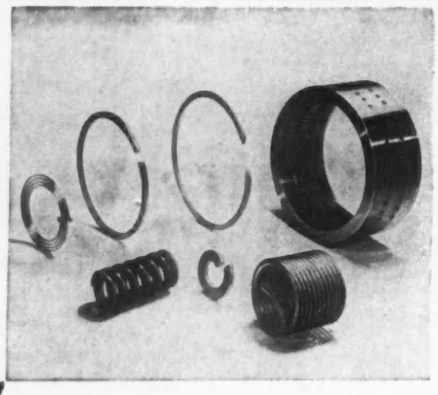

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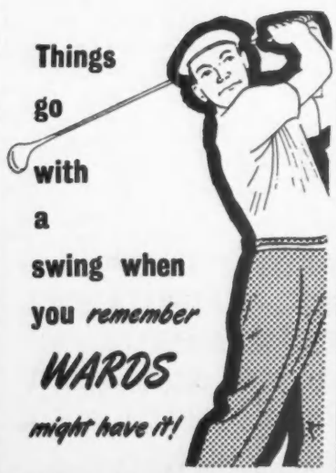

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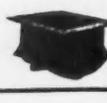

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March 1	**Machine tools and miscellaneous stores,** including :—	M.O.A. Storage Depot, **Byley, Nr. Middlewich, Cheshire.** (Sale at Cheetham Town Hall, Manchester, 8.)	**J. H. NORRIS & SON** (Dept. L), 9, Albert Square, Manchester, 2. (Tel.: Blackfriars 8373.)
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March 8–11	**Machine tools and miscellaneous stores.**	M.O.A. Storage Depot, Royal Arsenal, **Woolwich, London, S.E.18.**	**FULLER, HORSEY, SONS & CASSELL** (Dept. L), 10, Lloyd's Avenue, London, E.C.3 (Tel.: Royal 4861.)
March 15	**Miscellaneous stores.**	Central Ordnance Depot, **Didcot, Berks.**	**SIMMONS & SONS** (Dept. L), 12, Station Road, Reading, Berks. (Tel.: 54025).
March 15–18	**Vehicles, earth moving and lifting equipment.**	M.O.A. Storage Depot, **Ruddington, Notts.**	**WALKER, WALTON & HANSON** (Dept. L), Byard Lane, Bridlesmith Gate, Nottingham. (Tel.: 54272.)
March 22–23	**Vehicles and miscellaneous stores.**	Central Ordnance Depot, **Bicester, Oxon.**	**MIDLAND MARTS, LTD.** (Dept. L), Market Square, Bicester, Oxon. (Tel.: 73.)
March 30	**Miscellaneous stores.**	Northern Command Ordnance Sub-Depot, **Barlow, Nr. Selby, Yorks.**	**BARTLE & SON** (Dept. L), 50–52, Merrion Street Leeds, 2. (Tel.: 2.0898.)
April 8	**Miscellaneous stores.**	Returned Stores Group, **Reed Hall, Colchester, Essex.**	**FENN, WRIGHT & CO.** (Dept. L), 146, High Street, Colchester, Essex. (Tel.: 3171.)

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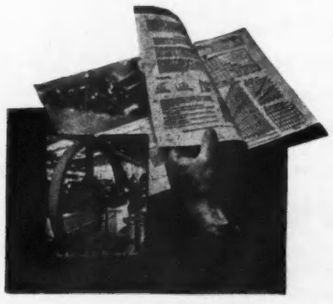

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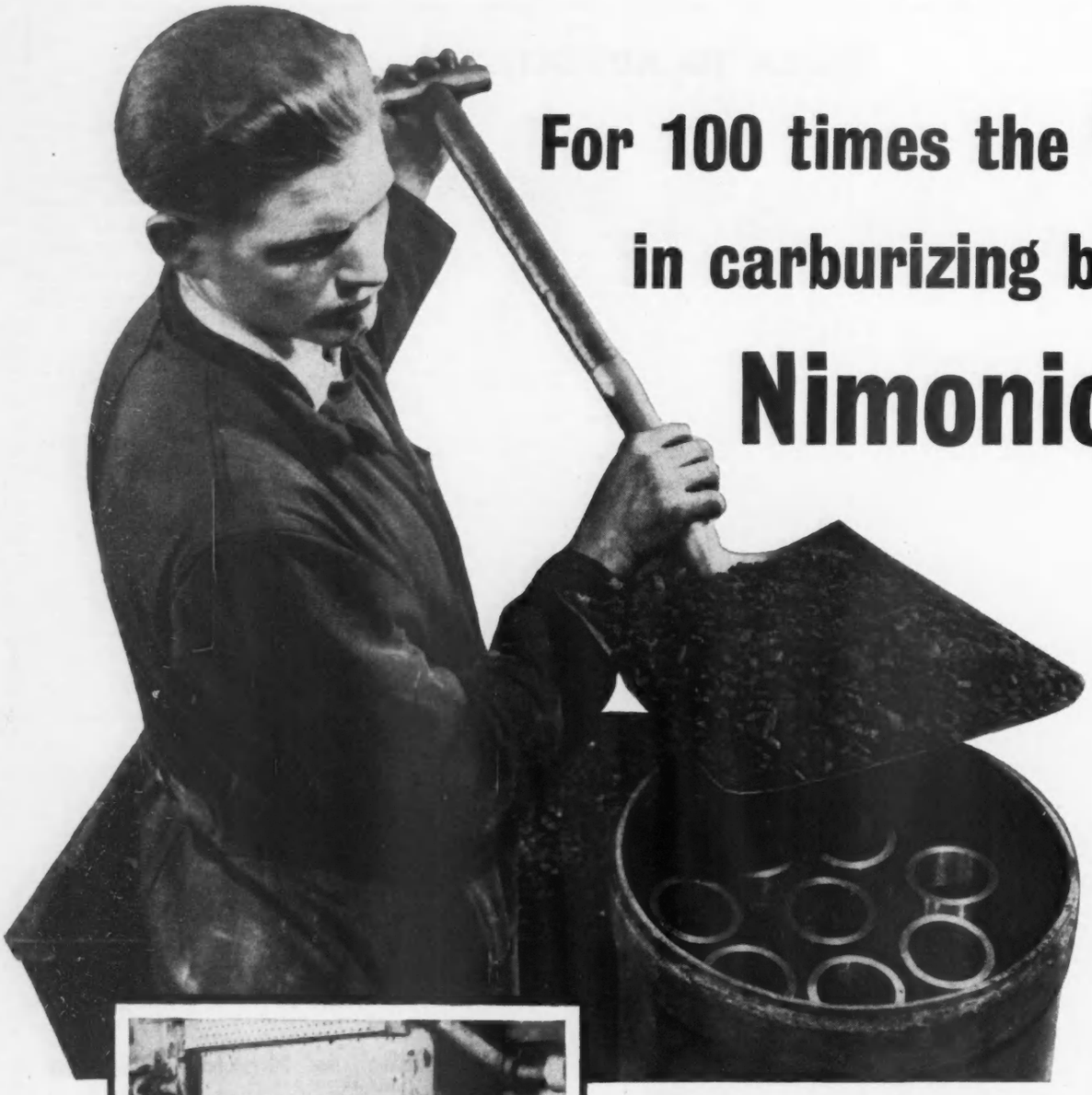

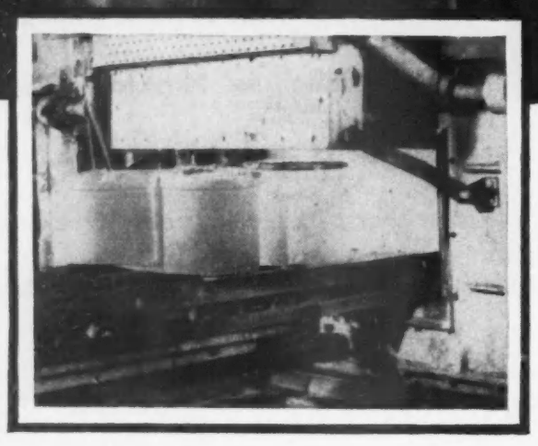

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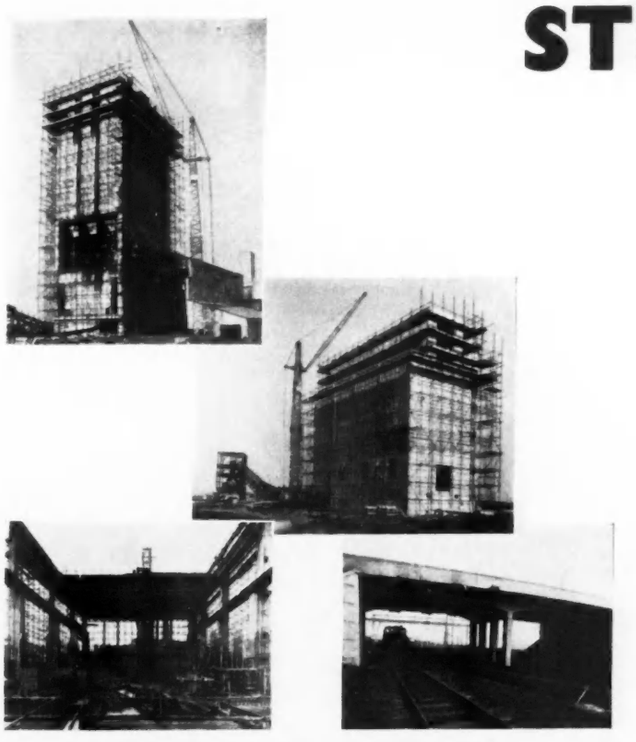

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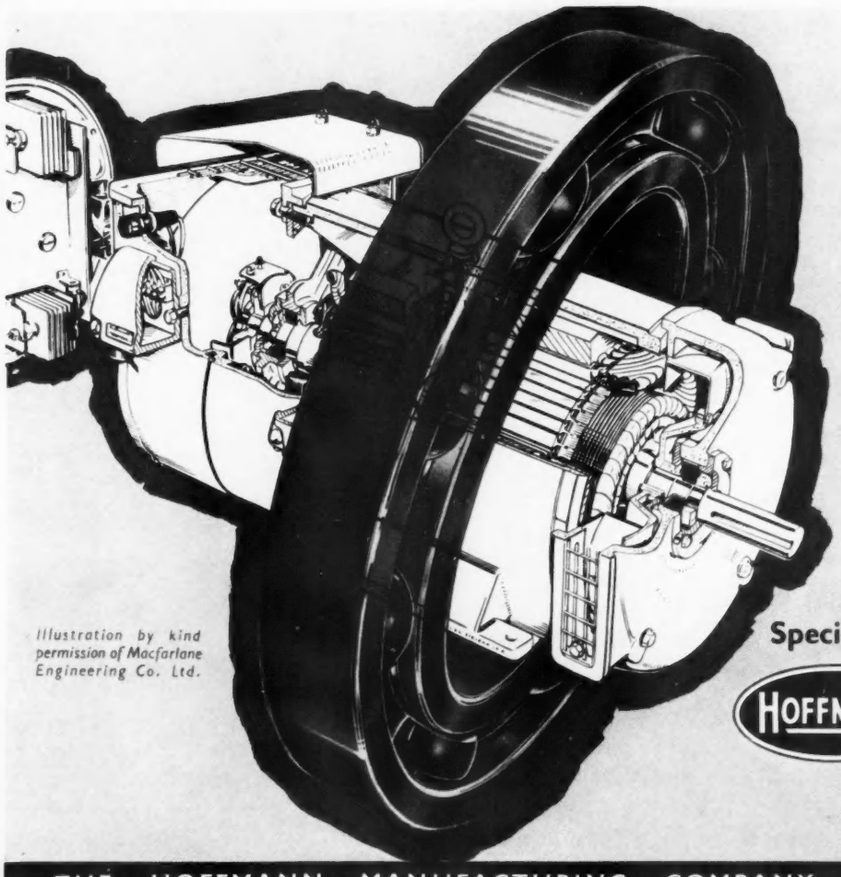

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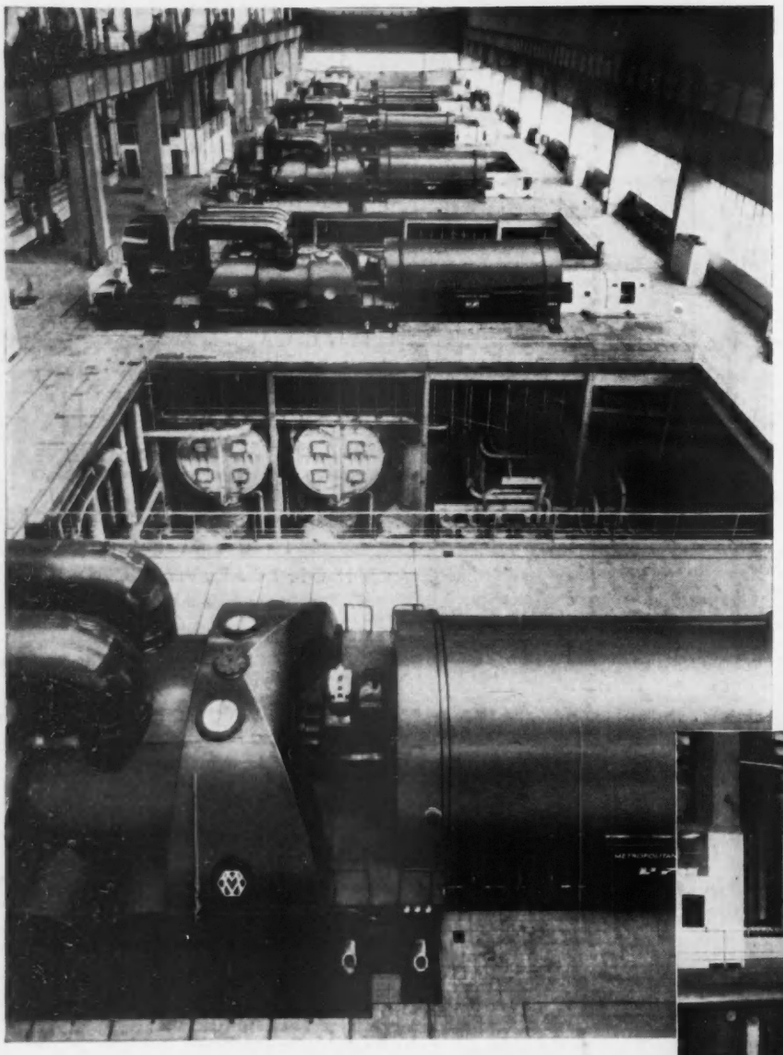

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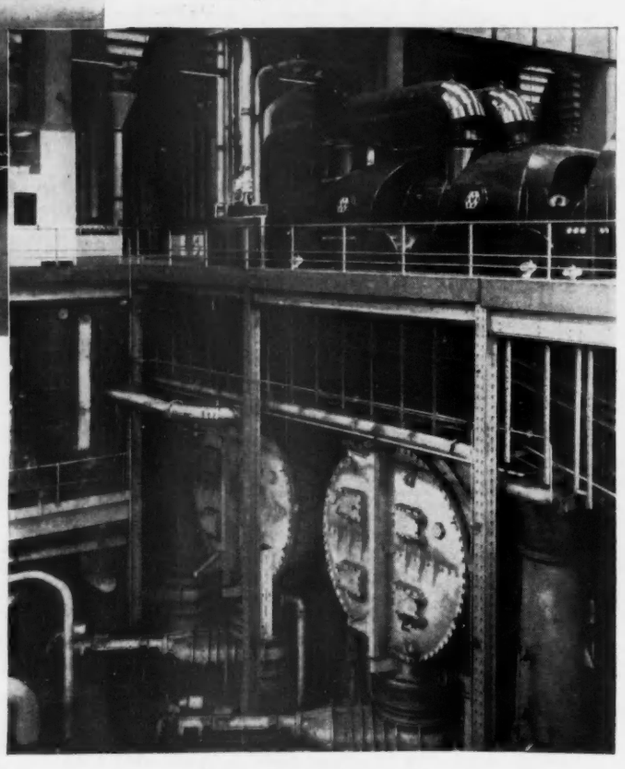

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